

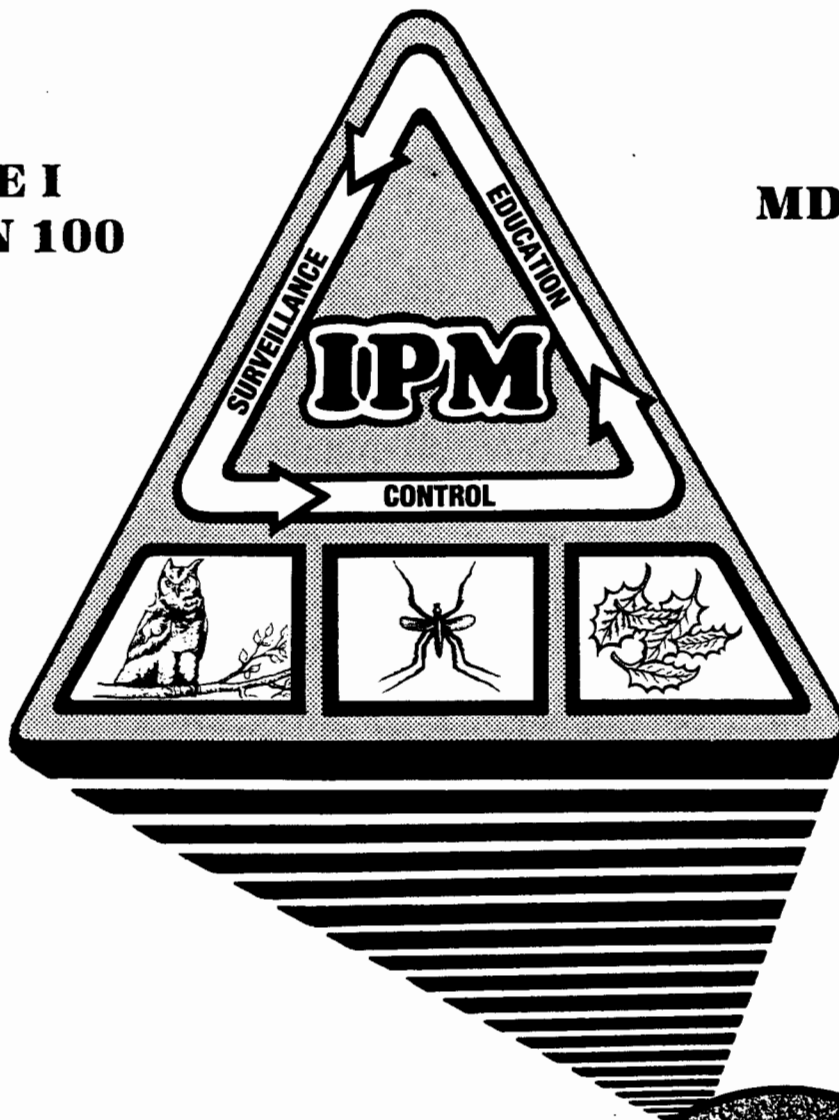


UNITED STATES ARMY  
ACADEMY OF HEALTH SCIENCES

# DEPARTMENT OF DEFENSE PEST MANAGEMENT COURSE

**PHASE I**  
**EDITION 100**

**MD 0142**



**1997**



## **DEVELOPMENT**

This subcourse is approved for resident and correspondence course instruction. It reflects the current thought of the U.S. Army Medical Department Center and School and conforms to printed Department of the Army doctrine as closely as currently possible. Development and progress render such doctrine continuously subject to change.

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## **ADMINISTRATION**

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## **CLARIFICATION OF TRAINING LITERATURE TERMINOLOGY**

When used in this publication, words such as "he," "him," "his," and "men" are intended to include both the masculine and feminine genders, unless specifically stated otherwise or when obvious in context.

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**US ARMY MEDICAL DEPARTMENT CENTER AND SCHOOL  
DEPARTMENT OF DEFENSE PEST MANAGEMENT COURSE  
FORT SAM HOUSTON, TEXAS 78234-6122**

**STUDENT INSTRUCTIONS**

1. **Application for Enrollment.** Your application for enrollment in the Department of Defense Pest Management Course (DoDPMC) correspondence course has been accepted.
2. **Course Design.** The DoDPMC is designed as an independent study program to qualify you for the DoD Pesticide Applicators Certification under the provisions of the Federal Insecticide, Fungicide, and Rodenticide Act, as amended, and the DoD 4150.7P, Plan for the Certification of Pesticide Applicators. The course is not intended as a comprehensive program of study for pest management, but as qualifying instruction for certification.
3. **DoDPMC Components.** The DoDPMC is made up of 3 subcourses:

MD0141, CORE Phase.  
MD0142, Phase I.  
MD0143, Phase II.

To complete the course, you will not be required to read outside material. However, referenced materials may be of assistance to you in understanding difficult subject matter.

4. **Components of this Subcourse.**

This subcourse consists of 13 lessons. The lessons are:

Lesson 1, Vegetation Management.

Lesson 2, Soil Fumigation.

Lesson 3, Plant Biology.

Lesson 4, Herbicides.

Lesson 5, Turfgrass Insects.

Lesson 6, Insects of Trees and Ornamental Plants.

Lesson 7, Aquatic Weeds.

Lesson 8, Fertilization.

Lesson 9, Identification and Control of Tree and Ornamental Plant Diseases.

Lesson 10, Forest Pest Management.

Lesson 11, Identification and Management of Turfgrass Diseases.

Lesson 12, Natural Resources Conservation Programs.

Lesson 13, Turfgrass Management.

5. **Credit Awarded.** Successful completion of this subcourse qualifies eligible students for certification in the following DoD pest control categories:

- ◆ Category 2 -- Forest pest control.
- ◆ Category 3 -- Ornamental and turf pest control.
- ◆ Category 3a -- Soil fumigation pest control.
- ◆ Category 5 -- Aquatic pest control.
- ◆ Category 6 -- Right-of-way pest control.
- ◆ Category 6a -- Grassland and non-crop agricultural pest control.

6. **Lesson Materials Furnished.** Lesson materials provided include this booklet. Solutions to lesson exercises are contained in the Appendix of this booklet.

7. **Procedures for Subcourse Completion.**

**Step 1.** Complete the subcourse lesson by lesson, reading each lesson and completing and checking the lesson exercises.

**Step 2.** Notify the Certifying Official that you are ready to take the final examination.

**Step 3.** The Certifying Official will notify you that the final examination has arrived. You and that individual will coordinate a time for you to take the closed-book examination.

**Step 4.** At the designated time and place, you will take the closed-book final examination.

**Step 5.** Your examination sheet will be graded. Within 2 to 3 weeks, you will be notified that you have passed or failed the examination.

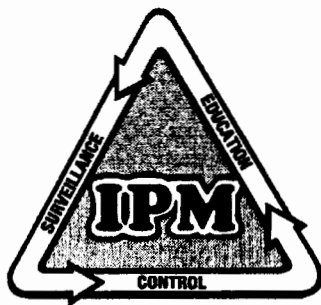
**NOTE  
QUALIFYING FOR THE  
DoD PESTICIDE APPLICATOR'S CERTIFICATION**

- ◆ Pass the CORE exam + PHASE I exam = DoD Pest Control Categories 2, 3, 3a, 5, 6, and 6a.
- ◆ Pass the CORE exam + PHASE II exam = DoD Pest Control Categories 7, 7a, and 8.
- ◆ Pass the CORE exam + PHASE I exam)  
+ PHASE II exam) = DoD Pest Control Categories 2, 3, 3a, 5, 6, 6a, 7, 7a, and 8.

8. **Examination Validity.** In order to maintain the validity of these examinations, you are not to discuss the contents of the examinations, give answers to anyone else, or reproduce the examination without permission.
9. **Course Completion/Certification.** In order to complete the course and qualify for DoD Pesticide Applicators Certification, you must achieve a minimum grade of 70 percent on each examination. You have 12 months from the time you are enrolled to complete the course. Should you require additional time, you may be granted an **extension of time** (a waiver) by contacting the Nonresident Instruction Branch, Fort Sam Houston, Texas.
10. **Examination Failures.** Examination failures will result in one retest if you score between 50 and 69 percent. You will be given up to 90 days to retake that examination. A score of less than 50 percent or failure to retest on the CORE examination will disqualify you for the DoD Pesticide Applicators Certification by correspondence. A score less than 50 percent or failure of a retest on Phase I or Phase II examinations will disqualify you for the DoD Pesticide Applicators Certification by correspondence in the DoD pest control categories covered in the failed Phase.
11. **Student Comment Sheet.** Be sure to provide us with your suggestions by filling out the Student Comment Sheet (found at the back of this booklet) and returning this sheet with the examinations. In this way, you will help us improve the quality of this course.
12. **Study Suggestions.**

The following suggestions may be helpful to you in completing this subcourse:

- ◆ Read and study each lesson carefully.
- ◆ Complete the subcourse lesson by lesson. After completing each lesson, work the exercises at the end of the lesson, marking your answers in this booklet.
- ◆ After completing each set of lesson exercises, compare your answers with those on the solution sheet which follows the exercises. If you have answered an exercise incorrectly, check the reference cited after the answer on the solution sheet to determine why your response was not the correct one.
- ◆ As you successfully complete each lesson of a subcourse, go on to the next. When you have completed all of the lessons, notify Certifying Official that you are ready to take the final examination of that subcourse. Alternately, you may wait until you have completed all of the lessons in all subcourses, and request all three final examination at the same time.



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## LESSON ASSIGNMENT

<b>LESSON 1</b>	--	Vegetation Management.
<b>LESSON ASSIGNMENT</b>	--	Paragraphs 1-1 through 1-26.
<b>TERMINAL LEARNING OBJECTIVE</b>	--	Information gained in this lesson should enable you to use integrated pest management techniques to control unwanted vegetation in a variety of situations occurring on military facilities and during military activities.
<b>SPECIFIC LESSON OBJECTIVES</b>	--	After completing this lesson, you should be able to:  1-1. Identify the harmful effects of weedy plant growth.  1-2. Identify the means in which weeds are spread from place to place.  1-3. Identify methods for preventing weed growth and eliminating weeds in existing plantings.  1-4. Plan a weed control program.
<b>SUGGESTION</b>	--	After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 1

### VEGETATION MANAGEMENT

#### Section I. GENERAL INFORMATION

#### 1-1. INTRODUCTION

Anyone who has ever attempted to grow the simplest garden, or tend even a small lawn, is aware of unwanted plants; weeds, which complicate the gardener's life by growing in the space we consider our own. Most people are not aware of the millions of dollars spent each year for weed control, or of the millions of dollars lost due to lost agricultural productivity. In fact, weedy plants compete with man for the use of

the soil, thus affecting our food supply as well as the landscapes planted for our pleasure.

#### 1-2. WEEDS DEFINED

Weeds are often described simply as "undesirable plants," or "plants growing out of place," both accurate but incomplete statements.

**a. Definition.** Weeds can be defined as plants with harmful or objectionable characteristics, growing where they are not wanted, and often growing where we want another plant to grow.

**b. "Succession."** Weeds are "early successional plants." "Succession" is a term describing the transition states of an ecological system as it moves toward a steady state or

"climax" system. Weedy plants invade and occupy disturbed sites and bare soil, thus beginning the successional process. The weeds will eventually give way to other later successional plants if the site is left undisturbed for years. Agriculture, landscaping, and construction activities disturb the soil, opening a niche for weeds to occupy.

### 1-3. GROWTH HABITS

Weeds have evolved a number of characteristics to survive in harsh, competitive situations. Most weeds can endure under conditions which kill desirable plants.

**a. Regeneration.** Many weeds, for example, can regenerate lost or damaged parts. Many weeds can reproduce from seeds and vegetative parts if seeding is prevented (under close mowing). Sow thistle, for example, can spread several yards in one season from the roots alone. Cultivation of such a plant may only scatter the roots into new environments.

**b. Leaf Size.** Many weeds have evolved small-size or modified leaves to reduce moisture loss. Cultivated plants have large leaf surface to maximize photosynthesis and growth, but the increased growth comes at the cost of higher water requirements.

**c. Flowers/Seeds.** Many weeds (not all) have small and inconspicuous flowers. A weed can often produce viable seeds before the plant is noticed.

**d. Defensive Mechanisms.** Many weeds produce defensive mechanisms such as spines, stiff hairs, sticky substances, bad taste, or odor. Domestic animals and other natural enemies avoid weeds.

**e. The "C-4" Photosynthetic Pathway.** Some weeds, particularly grasses, use the "C-4" photosynthetic pathway. This photosynthetic pathway is more efficient than the more common "C-3" pathway of most cultivated plants. C-4 weeds grow faster and use water more efficiently than C-3 crops.

**f. Viable Seeds.** Weeds may produce thousands or hundreds of thousands of viable seeds. These seeds may live for years buried in the soil. Weed seeds may germinate after 20 to 40 years of burial.

## Section II. HARMFUL EFFECTS OF WEED GROWTH

### 1-4. REDUCTION IN CROP YIELD

Weeds cause serious reductions in crop yield. Weeds directly compete with crop plants for sunlight, soil nutrients, and water. Because weeds often grow faster and germinate sooner than cultivated plants, weeds are successful competitors. Yield is reduced because fertilizer, water, and sunlight is not available for the crop.

### 1-5. INCREASE IN AGRICULTURAL/ LANDSCAPE OPERATIONS COST

Weeds increase the cost of agricultural and landscape operations.

- ◆ Weed control programs are expensive, often amounting to one-tenth to one-third of the total value of the crop.
- ◆ The expensive processes of soil cultivation and herbicide application could be largely eliminated from agriculture if weed control weren't necessary.
- ◆ Weeds growing in turf and landscaped areas are controlled with herbicides or labor-intensive hand cultivation.

### 1-6. HOST TO UNDESIRABLES

Many weed species host plant diseases or insects which then attack desirable plants. Some diseases attack both the weed and the crop, while others attack the crop and spend part of their life cycle on a botanically unrelated weed. Some weed species host crop-destroying insects or arthropods (such as mosquitoes or ticks) which vector human diseases.

## 1-7. POSSIBLY POISONOUS

Weeds may be poisonous to livestock or human beings.

- ◆ Poisonous weeds. Some of the better known poisonous weeds are black nightshade, jimson weed, foxglove, pokeweed, and croton.
- ◆ Nonpoisonous weeds. Other weeds are not poisonous, but have spines or thorns which can wound livestock and damage the digestive system of cattle or horses. This group includes sandbur, wild oats, puncture vine, and Russian thistle.
- ◆ Strong-flavored weeds. Another group of weeds have very strong flavors. These flavors will taint milk produced by dairy cattle feeding on the weeds. These plants include wild garlic, wild onion, and bitterweed.

## 1-8. ALLERGIC REACTIONS/FIRE HAZARD

Some weeds produce pollen or sap which causes allergic reactions. Weeds topgrowth may dry in winter and become a fire hazard.

## 1-9. URBAN DAMAGE

The roots of weed trees, such as tree-of-heaven or china berry, can damage pavement, sidewalks, and other structures. Birds eat china berry seeds and deposit the seeds near houses. The quick-growing tree can crack house foundations if not removed immediately.

## 1-10. AESTHETIC DAMAGE

Weeds growing in lawns and landscapes cause aesthetic damage which very few homeowners or landscape managers will tolerate. Anyone visiting a high-visibility landscape, such as a golf course or military facility, expects and demands a weed-free environment.

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## Section III. WEED DISSEMINATION

## 1-11. WORLDWIDE

Many weeds are almost distributed worldwide. Weeds have succeeded in expanding into new territories because of biological mechanisms, such as winged or floating seeds, and also because of human activities.

## 1-12. TRANSPORTED BY MAN

Man has inadvertently contrived to transport injurious plants across the globe. The weeds which now plague farmers and landscape managers were often unknown in the area one hundred years ago. Noxious weeds which now cover millions of acres in the Pacific Northwest or choke the lakes of Florida were brought into the area only a century ago. There are several ways men have introduced weeds into new areas.

### a. Ornamental Plants Turned Wild.

Ornamental plants may escape from cultivation and become established as wild plants. Examples of escaped ornamentals include Japanese honeysuckle; Foxglove; Scotch broom; morning-glory; and sweet brier.

### b. Contamination of Agricultural

**Seeds.** Weed seeds can contaminate agricultural seeds and be planted along with the crop.

- ◆ Weeds grow in such close association with crop plants that the seeds are harvested together.
- ◆ If the seeds are similar in size and shape, it is difficult to separate the weeds without special equipment.
- ◆ The Federal Seed Act of 1939 requires labelling of seeds offered for sale in the United States. The label must state the percentage of noxious weed seeds contained in the lot.

**c. Harvested with Crop.** Producers of hay and animal feeds sell those commodities far from the fields where they were grown.

- ◆ For example, growers ship timothy hay produced in central Washington state across the Pacific to Japan.
- ◆ Weed seeds or vegetative parts are harvested along with the crop and moved into new areas.
- ◆ Noxious weeds such as spotted knapweed reached the northwestern United States as a contaminant of animal fodder.

**d. Picked up by Equipment.** Farm machinery and mowers pick up weed seeds during operation and scatter the seeds from one area to another.

**e. Present in Landscape Materials.** Landscapers sometimes use straw mulch and topsoil or compost materials which are contaminated with weed seeds or plant parts.

**f. Out-of-Control Plants Become Weeds.** Biologists have mistakenly established plants which were believed to be beneficial, but later became noxious weeds.

(1) Kudzu. For example, the US Soil Conservation Service introduced kudzu to the southern United States from its native Japan.

- ◆ Biologists believed the vigorous legume could stabilize and enrich eroding soils damaged by cotton cultivation.
- ◆ Kudzu proved to be fairly effective at erosion control, but the fast-growing vine has covered huge areas of woodland and retards the growth of timber crops.

(2) Cogongrass. The US Department of Agriculture introduced cogongrass to the southeast to be used as cattle fodder. Cattle shun the coarse grass, which is now widely distributed across the region.

#### **MAN INTRODUCES WEEDS INTO NEW AREAS**

- ◆ Ornamental plants turned wild.
- ◆ Weed seed mixed with agricultural seeds.
- ◆ Weed seeds harvested with crops.
- ◆ Weed seeds picked up by equipment.
- ◆ Weed seeds present in landscape materials.
- ◆ Out-of-control plants become weeds:
  - Kudzu.
  - Cogongrass.

#### **1-13. OTHER MECHANISMS OF WEED DISSEMINATION**

Other mechanisms of weed dissemination are animals, wind, and flowing water.

**a. Wind.** Weeds adapted to wind dissemination include dandelion, milkweeds, and thistles.

**b. Water.** Weeds with floating and water-resistant seeds include wild mustards, ragweed, cocklebur, curly dock, and many others.

**c. Animals and Birds.** Animals may carry the burs of some weeds, such as cocklebur, sandbur, and beggar-ticks on their fur. Other weed seeds pass through the digestive system of animals without losing viability. Birds scatter the seeds of poison ivy, poison sumac, and choke-cherry after feeding on the fruit. Domestic animals scatter weed seeds eaten along with contaminated hay or feeds.

### **OTHER METHODS OF WEED DISSEMINATION**

<u>The vehicle</u>	<u>Weed disseminated</u>
♦ Wind.	Dandelions Milkweeds. Thistles.
♦ Water.	Wild mustards. Ragweed. Cocklebur. Curly dock.
♦ Animals.	Cockleburs. Sandsburs. Beggar-ticks.
♦ Birds.	Poison ivy. Poison sumac. Choke-cherry.

## **Section IV. WEED MANAGEMENT**

### **1-14. PREVENT-ERADICATE-CONTROL**

Vegetation managers should try to prevent the spread of weeds into an area, then eradicate any weeds which have been introduced. If prevention and eradication have failed and a weed species is well-established, the manager must control the weed, keeping the weed population to an acceptable level.

### **WEED CONTROL**

- ♦ Prevent spread of weeds.
- ♦ Eradicate existing weeds.
- ♦ Control weeds.

### **1-15. WEED PREVENTION**

Prevention of weeds is accomplished with a number of techniques.

a. **Clean Seed.** Commercial seed growers must label their seeds as to the percentage of noxious weeds. Managers should buy the cleanest seed available. Seeds are only a small portion of the total expense of a landscaping job.

b. **Topsoil.** Commercially available topsoil is a potential source for weed seeds and plant parts. Managers should purchase sterilized or composted top soil. The composting process kills most weed seeds.

c. **Artificial Soils.** The use of artificial, sand-based soils for athletic fields and golf greens is an effective weed prevention technique. The sand-based soils are free of weed seeds and have nearly perfect drainage. Good soil drainage reduces weed infestation.

d. **Clean Equipment.** Mowing or cultivating equipment should be cleaned before leaving a weed-infested field.

### **1-16. WEED ERADICATION**

Eradication involves complete destruction of an introduced weed. The vegetation manager must destroy plant tops, root system, and seeds. Vegetation managers use herbicides and mechanical methods to kill weeds before they become established.

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## **Section V. WEED CONTROL**

### **1-17. INFORMATION**

Weed control is an effort to reduce the population of an established weed species. Nonchemical weed control may be accomplished in a number of ways.

## **NONCHEMICAL WEED CONTROL METHODS**

- ◆ Cultivation.
- ◆ Mulch.
- ◆ Mowing.
- ◆ Flaming.
- ◆ Hot water or steam.
- ◆ Soil drainage improvement.
- ◆ Irrigation.
- ◆ Fertilization.
- ◆ Biological control

### **1-18. CULTIVATION**

Cultivation is done by hoeing, rotary tilling, and disking. Cultivation kills weeds by uprooting the plant, so the root system dries. This technique is as old as agriculture and is still practiced by homeowners, farmers, and landscape managers.

- ◆ Cultivation works best when the soil is dry, air temperature is high, and plants are young.
- ◆ It's an expensive, labor intensive process.
- ◆ Cultivation may injure the roots of trees and ornamentals (if machinery is used) and bring buried weed seeds to the surface.

### **1-19. MULCH**

Mulch is a layer of organic (or inorganic) material used to retard weed growth around ornamental plants. A deep layer of mulch greatly reduces weed growth and may improve soil conditions. The most common mulches are shredded tree bark, wood chips, and crushed stone. Landscape fabrics, which allow air and water to penetrate, covered with organic material are usually the best mulch. Plastic films prevent weed growth, but do not allow water or air to penetrate.

### **1-20. MOWING**

Mowing controls most broadleaf (dicotyledon) weeds in turfgrass. Broadleaf plants have meristematic tissue (rapidly growing, undifferentiated cells) or "growing points" located at stem tips and leaf axils. When the growing point is destroyed, the plant usually dies. Annual weeds, which have limited root systems, are most susceptible to mowing. Grasses have growing points located in the crown, which is at ground level, and tolerate close mowing. Prostrate broadleaf plants also tolerate close mowing.

### **1-21. FLAMING**

Flaming is the use of a weed burner, essentially a flame-thrower, to kill aboveground plants. The flame heats plant cell contents to near-boiling, and the cell wall bursts. The aboveground plant is killed by desiccation. Roots are unharmed by flaming.

### **1-22. HOT WATER OR STEAM**

Hot water or steam kills plants by melting a waxy coating on plant leaf surfaces. Plants cannot retain moisture without the waxy leaf coating, and the leaves desiccate. Roots are usually unharmed.

### **1-23. SOIL DRAINAGE IMPROVEMENT**

Soil drainage improvement is often effective at controlling established weeds or preventing establishment.

- ◆ Weed seeds are mostly found in the top inch of soil; the root system of annual weeds is only a few inches deep.
- ◆ Improved drainage dries out the soil surface and greatly reduces weed seed germination and weed growth.

### **1-24. IRRIGATION**

Irrigation is a tool for weed control. Weeds and weed seeds usually inhabit the top few inches of soil. Proper irrigation keeps the soil surface dry.

- ♦ The key words for proper irrigation are deep and infrequent.
- ♦ Irrigation water is applied as seldom as possible, but in enough volume to deeply wet the soil profile.
- ♦ Deep-rooted crops, like turfgrass, mine water from deep in the soil, while shallow-rooted weeds dry out.
- ♦ Frequent and shallow irrigation encourages weed growth.

#### 1-25. FERTILIZATION

Fertilization can control weed growth by stimulating the growth of beneficial plants.

- ♦ For example, turfgrasses are extremely competitive plants. Turfgrass species can usually produce a dense groundcover which is extremely resistant to weed infestation, if sufficient fertilizer nutrients are available.

#### 1-26. BIOLOGICAL CONTROL

Biological control is the use of insects, fungus diseases, and other organisms to control weeds.

**a. Find Natural Enemies.** Many weeds are exotic species with few natural enemies in North America. If natural enemies are found and established in North America, some level of weed control may occur. Organisms used for biological control must be thoroughly tested to ensure they will not damage similar plants or cause unforeseen problems.

**b. Biological Control--A Success Story.** Biological control has been very successful against some weeds (water hyacinth, alligatorweed, water lettuce, for example), but it's often slow and requires a lot of research. The benefit of biological control is seen after a control organism is established, and exerts a level of control indefinitely.

### EXERCISES, LESSON 1

**REQUIREMENT.** The following exercises are to be answered by selecting the correct letter, completing the incomplete statement, or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

1. Succession may be defined as \_\_\_\_\_

2. List four harmful effects of weed growth.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_

3. Weeds are distributed worldwide in a number of ways. List five of the ways in which man transports weeds.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

4. Other mechanisms of weed dissemination include:

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_

5. To eradicate weeds, a vegetation manager must destroy \_\_\_\_\_

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6. How does cultivation control weeds?

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7. The use of a flame-thrower to kill aboveground plants is the description of the weed control process termed \_\_\_\_\_.

8. \_\_\_\_\_ control of weeds has been very successful against weeds such as the water hyacinth, alligatorweed, and water lettuce.

9. \_\_\_\_\_ covered with \_\_\_\_\_ are the best mulch to control weeds.

10. How do hot water or steam kill plants?

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**END OF LESSON EXERCISES**



## LESSON ASSIGNMENT

<b>LESSON 2</b>	--	Soil Fumigation.
<b>LESSON ASSIGNMENT</b>	--	Paragraphs 2-1 through 2-11.
<b>TERMINAL LEARNING OBJECTIVE</b>	--	Information gained in this lesson should enable you to determine when soil fumigation is an appropriate technique and to utilize soil fumigants as part of an integrated pest management program.
<b>SPECIFIC LESSON OBJECTIVES</b>	--	After completing this lesson, you should be able to:  2-1. Identify those pesticides commonly used as soil fumigants.  2-2. Identify situations in which soil fumigants could be used to achieve program objectives.  2-3. Discuss the proper techniques for applying soil fumigants.  2-4. Determine if soil fumigation should be used to solve a particular vegetation management problem.
<b>SUGGESTION</b>	--	After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 2

### SOIL FUMIGATION

#### 2-1. INTRODUCTION

Soil is extremely rich in living organisms, although this is not obvious to the casual observer. Biologists believe topsoil is the most biologically active part of the entire biosphere. Plant roots, insects, nematodes, vertebrate animals, bacteria, fungi, plant seeds, and many other life forms are found in soil. Most of these organisms are beneficial from an ecological and agricultural standpoint. However, in certain circumstances, we want to produce a sterile planting media. Soil fumigants are a tool we can use to produce a pest-free soil.

#### 2-2. NATURE OF FUMIGANTS

A fumigant is a volatile or volatilizable chemical used as a pesticide. The fumigant may be a solid or liquid during storage, but it becomes a fume or vapor upon release. The fumes penetrate and fill all available space, so all pests within a confined space are exposed to the fumigant. The fumigant rapidly volatilizes into the atmosphere once the confined space is ventilated.

#### 2-3. NEED FOR SOIL FUMIGATION

We use soil fumigants for "pre-plant" soil preparation. Soil is essentially sterilized by fumigation before seeds or vegetative parts are planted. New plants then grow in a pest-free soil for some time with no competition from weeds,

nematodes, insects, or soil-borne diseases. Soil fumigation is expensive and labor-intensive. Managers use this practice only on valuable, high-maintenance crops such as tobacco, greenhouse and nursery plants, flowers, and high-maintenance turfgrass (golf greens and tees).

#### 2-4. APPROPRIATE SITUATIONS

Farmers use soil fumigants when a seedling plant is weak and competes poorly with weeds and other pests. For example, tobacco seeds are tiny, and the seedlings cannot develop properly in a biologically active soil. Tobacco growers sterilize a small area of soil (the tobacco "bed") and sow the seeds. The grower transplants seedlings to the field after they reach sufficient size. Greenhouse managers and nurserymen routinely fumigate soil between crops. Golf course managers fumigate weed-infested golf greens or tees prior to renovation. Fumigation kills infested turfgrass and weeds as well, leaving a clean soil media. The golf course manager reseeds or plants sod to finish the renovation. Turfgrass is strongly competitive, but customers do not easily tolerate any weeds on golf greens or tees. Growers use soil fumigants to sterilize loads of topsoil, turfgrass sod farms, and wildflower plantings.

#### 2-5. DESIRED FUMIGANT CHARACTERISTICS

Currently, available fumigants are not perfect.

- ◆ The perfect fumigant will rapidly kill weed seeds, vegetative plant parts and other soil organisms to a depth of six to eight inches; but it will be safe to use, easy to apply, and inexpensive!
- ◆ The perfect soil fumigant will also leave the soil immediately after treatment is complete, so replanting can begin.
- ◆ Actual soil fumigant materials include methyl bromide, dazomet, metam-sodium, chloropicrin, steam, and soil solarization.

#### **SITUATIONS FOR SOIL FUMIGATION**

- ◆ Farmers--between crops.
- ◆ Greenhouse managers and nurserymen--between crops.
- ◆ Golf course managers--fumigate weed-infested golf greens or tees before renovation.
- ◆ Growers--sterilize topsoil loads, turfgrass sod farms, and wildflower plantings.

#### 2-6. METHYL BROMIDE

a. **Description.** Methyl bromide is a colorless, odorless gas at normal temperature and pressure. The gas liquifies under moderate pressure, so it is sold in the form of a liquified gas with a density of 14.4 lb/gal. Chloropicrin ("tear gas") is often added to methyl bromide as a warning agent, increasing methyl bromide's effectiveness against soil borne diseases.

b. **The Signal Word.** The signal word for methyl bromide is DANGER, indicating this is a Class I or extremely dangerous pesticide. Methyl bromide is a poison which can cause respiratory distress, cardiac arrest, and central nervous system effects. The Environmental Protection Agency plans to cancel all uses of methyl bromide in the year 2005. This action is planned because methyl bromide depletes the ozone layer.

c. **Application.** Methyl bromide must be confined under a polyethylene cover to be effective. The fumigant is injected under an airtight cover and maintained gas-proof for 24 to 96 hours. Seeds (or vegetative propagules) may

be planted two to three days after the cover is removed. The soil is aerated or tilled to a depth of six to nine inches prior to fumigation.

## 2-7. DAZOMET<sup>R</sup>

**a. Description.** Dazomet<sup>R</sup> is a white-slightly gray, crystalline solid in pure form. The solid pesticide decomposes in water to yield fumigant vapors. Dazomet<sup>R</sup> kills soil-borne diseases, plant roots, germinating seeds, and soil insects.

**b. The Signal Word.** The signal word for technical grade Dazomet<sup>R</sup> is DANGER, indicating a Class I pesticide. Dust and granule formulations (which are used in the field) of Dazomet<sup>R</sup> are less toxic and carry the signal word WARNING or CAUTION.

**c. Application.** Dazomet<sup>R</sup> is applied as a dust or granule and confined under a plastic cover or by daily watering (a "water seal"). The soil is aerated or tilled to a depth of six to nine inches prior to fumigation and watered. The fumigant is confined to the soil for at least two days, although longer exposures are more effective. Seeds are planted 20 to 30 days after the cover is removed.

## 2-8. METAM-SODIUM

**a. Description.** Technical grade metam-sodium is a white crystalline solid. metam-sodium is soluble in water and ethanol, so it's sold as a soluble concentrate and an aqueous solution.

**b. The Signal Word.** The signal word for metam-sodium is CAUTION, indicating it's a Class III, or slightly toxic pesticide. One formulation, "Metam Fluid," is a moderately toxic Class II pesticide.

**c. Application.** We apply metam-sodium in several ways: as a liquid drench, injected into the soil, or injected into irrigation systems. Metam-sodium volatilizes in the soil. Best results are obtained by watering every day after treatment to maintain a water seal, or the fumigant may be confined with a plastic cover. The fumigant is confined to the soil for a minimum of two days, although longer exposure

is more effective. Seeds may be planted 15 to 20 days after treatment. Soil is rototilled or disced before seeding to release any trapped fumigant.

## 2-9. CHLOROPICRIN

**a. Description.** Most of us recognize chloropicrin from its use as the chemical irritant "tear gas." We are less familiar with chloropicrin as a pesticide. Chloropicrin is a heavy, colorless liquid with an intensely irritating odor.

**b. The Signal Word.** Chloropicrin carries the signal word DANGER, indicating a Class I or extremely dangerous pesticide. The Environmental Protection Agency sets a fumigation limit of 0.1 ppm for chloropicrin before a respirator is necessary.

**c. Characteristics.** Chloropicrin is highly toxic by inhalation, toxic by ingestion, a severe skin and eye irritant, and can cause injury to the heart. Methyl bromide and chloropicrin are often mixed, with chloropicrin at concentrations of two percent or less. Chloropicrin is considered an inert ingredient at this concentration for use as a warning agent. Chloropicrin is considered an active ingredient, effective against nematodes, bacteria, fungi, insects, and weeds, at any level greater than two percent.

## 2-10. STEAM

**a. Description.** Steam is a soil fumigant effective against soil-borne diseases, weeds, soil insects, nematodes, and germinating seeds. Greenhouse and nursery managers have used steam to sterilize soil since the late 1800's, but the technique is impractical for very large areas because of the large equipment needed to produce and retain sufficient steam.

**b. Application.** Steam must be retained in soil for a minimum of 30 minutes to be effective. Boilers are used to generate the steam, which is injected into a container of soil. Steam is injected into truckloads or wagonloads of soil under a tarpaulin which retains the heat. Mobile boilers can sterilize soil in open fields by injecting the steam and rolling the soil surface to retain the heat.

## 2-11. SOIL SOLARIZATION

We can effectively sterilize soil using only a clear plastic sheet and sunlight, given sufficient time. Soil is tilled with a rototiller or disc to the desired depth (six to nine inches is usually enough). Water is applied to the tilled soil, and a sheet of clear plastic is used to cover the area. Sunlight penetrates the clear plastic and creates intense heat (in excess of 130°F) in the wet soil. The heat kills weed seeds, nematodes, insects, and some fungal diseases. Soil solarization requires intense sunlight and temperatures above 85°F to succeed. Effective soil sterilization requires a minimum of four weeks.

### SOIL FUMIGANTS

- ◆ Methyl Bromide.
- ◆ Dazomet.
- ◆ Metam-sodium.
- ◆ Chloropicrin.
- ◆ Steam.
- ◆ Soil solarization.

## EXERCISES, LESSON 2

**REQUIREMENT.** The following exercises are to be answered by selecting the correct letter, completing the incomplete statement, or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

1. The purpose of soil fumigants is \_\_\_\_\_.

2. During storage, a fumigant may be either a solid or liquid. What happens to it once released? \_\_\_\_\_

3. List four characteristics of the perfect fumigant.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_

4. Methyl bromide is a colorless, odorless fumigant classified as extremely dangerous. In the year 2005, the Environmental Protection Agency plans to cancel all uses of this pesticide because \_\_\_\_\_

5. Dazomet is applied as a dust or granule and confined under a plastic cover or by daily watering. Seeds may be planted \_\_\_\_\_ days after the cover is removed.

6. Metam-sodium, a white crystalline solid, is soluble in water and ethanol. List three ways in which it can be applied.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

7. Chloropicrin, also called "tear gas," is effective against \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_

at any level greater than two percent.

8. Why is steam as a soil fumigant impractical for very large areas?

\_\_\_\_\_  
\_\_\_\_\_

9. List two essentials necessary for soil solarization to be successful as a soil fumigant.

- a. \_\_\_\_\_
- b. \_\_\_\_\_

**END OF LESSON EXERCISES**



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## LESSON ASSIGNMENT

<b>LESSON 3</b>	--	Plant Biology.
<b>LESSON ASSIGNMENT</b>	--	Paragraphs 3-1 through 3-24.
<b>TERMINAL LEARNING OBJECTIVE</b>	--	Information gained in this lesson should enable you to utilize the principles of plant biology to control unwanted vegetation or promote the growth of beneficial vegetation on property controlled by the Army.
<b>SPECIFIC LESSON OBJECTIVES</b>	--	After completing this lesson, you should be able to:  3-1. Define the following terms: <ul style="list-style-type: none"><li>◆ Gymnosperms.</li><li>◆ Angiosperms.</li><li>◆ Monocotyledon.</li><li>◆ Dicotyledon.</li><li>◆ Annual plant.</li><li>◆ Biennial plant.</li><li>◆ Perennial plant.</li></ul> 3-2. Define respiration, photosynthesis, and translocation.  3-3. Identify the three kinds of photosynthetic pathways found in plants.  3-4. Identify the factors which influence plant growth.
<b>SUGGESTION</b>	--	After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 3 PLANT BIOLOGY

### Section I. GENERAL INFORMATION

#### 3-1. INTRODUCTION

Most military installations allocate a high percentage of total pesticide use to management of weedy vegetation. Installation personnel also

use other chemicals in vegetation management, including fertilizers, growth regulators, wetting agents, and various soil amendments. To effectively control unwanted plants and to culture desirable plants, we must understand basic principles of plant biology.

#### 3-2. INFORMATION IN THIS LESSON

In this lesson, we explain some basic plant characteristics and plant life processes. We have provided a discussion of the different photosynthetic pathways found in plants, and the effect these pathways may have on vegetation

management. Vegetation managers should pay particular attention to our discussion of plant growth factors and weed strategies.

## Section II. PLANT TYPES

### 3-3. THALLOPHYTES

Botanists divide the plant kingdom into many groups with similar characteristics for ease of classification and study. No botanist can ever finalize plant classification because knowledge of the plant kingdom is continually increasing.

- ◆ Botanists currently recognize 12 divisions, which correspond to the phylum system used by zoologists.
- ◆ We use 10 divisions to classify the thallophytes--those plants not divided into root, stems, or leaves.
- ◆ Thallophytes have no vascular system and no seeds. Examples of thallophytes are the many groups of algae.

### 3-4. BRYOPHYTES

The bryophytes comprise another division of the plant kingdom. These spore-producing plants have no true vascular system. Examples of bryophytes are the liverworts, hornworts, and mosses.

### 3-5. TRACHEOPHYTES

Man has historically been most interested in the tracheophytes or vascular plants. We have found virtually all of the plants we use to produce food, fiber, erosion control, wood, or ornamental material in this group.

- ◆ The vascular plants have specialized conducting cells (xylem and phloem) to move water and dissolve materials throughout the plant body.
- ◆ Included are ferns, horsetails, and club

mosses, but the most important group of vascular plants, for human purposes, is the Spermatophyta or seed plants.

### 3-6. SEEDS

**a. Definition.** Seeds are structures formed by the Spermatophyta after fertilization. The seed consists of an embryo, a seed coat, and, usually, storage tissue. Two groups of seed plants, gymnosperms and angiosperms, are important to us.

**b. Gymnosperms (Naked Seeds).** Gymnosperms produce "naked" seeds, seeds not enclosed by floral structures. Pollen is deposited on or near the ovules. This group includes the cycads and the ginkgos, but the most important group from a human standpoint is the conifers.

**c. Seeds from Evergreens.** Foresters often call coniferous trees "softwoods" or "evergreens." These plants usually produce seeds on the surface of scales within woody seed cones. Conifers have needlelike leaves which are often green throughout the year.



**d. Angiosperm Seeds.** Angiosperms produce seeds enclosed within floral structures called carpels. Pollen is deposited on the stigma, and the nonmotile sperm are transferred to the ovule through a pollen tube.

#### e. Angiosperm (Flowering Plants).

Virtually everyone is familiar with the angiosperms, which we call "flowering plants." This group includes almost every plant used for food or ornamental purposes by man. Flowering plants may be further grouped into the dicotyledons and the monocotyledons.

- ◆ Dicotyledons. Dicotyledons have an embryo with two seed leaves or cotyledons. Cotyledons appear during germination and are soon replaced by true leaves as the seedling grows.
  - Dicotyledons have flower parts (petals, sepals, etc.) in four's or five's and netted-veined leaves.
  - Vascular tissue of the stem is in a cylinder, and vascular cambium (a layer of active cell division) is usually present.
  - This group includes trees and herbs (soft tissue plants). We can easily identify many of the plants around us as dicotyledons.
  - Other members of this group are roses, buttercups, spurge, potatoes, the mints, the legumes, and the composites, among others.
- ◆ Monocotyledons. Monocotyledons have an embryo with only one seed leaf or cotyledon.
  - These plants have flower parts in three's, and leaves have parallel veins. Vascular tissue of the stem is in scattered vascular bundles, and vascular cambium is usually absent.
  - Monocotyledons are mostly herbs, although one group, palms, form woody tissue. This group includes the grasses, the sedges, pineapples, orchids, and lilies, among others.

### Section III. PLANT LIFE CYCLES

#### 3-7. GROWING PLANTS

Vegetation managers find it useful to group plants according to life cycle. We can conveniently group seed plants into three large subdivisions based on life cycle. We use the terms "annual," "biennial," and "perennial" to describe these groups.

#### 3-8. ANNUAL PLANTS

Annual plants are short lived. The entire life cycle from germination to seed production takes only one growing season.

- ◆ We further group these plants into summer annuals, which germinate in spring and set seed sometime in the fall; and winter annuals, which germinate in fall and set seed in late winter or early spring.
- ◆ Annuals reproduce only from seeds. Many of these plants can produce large quantities of seed.
- ◆ Man has cultivated annual crop plants for centuries, carefully saving seeds from year to year.
- ◆ Annual weeds usually grow quickly and produce a large number of seeds.
- ◆ Annual plants do not generate an extensive root system during their short life span.

#### 3-9. BIENNIAL PLANTS

Biennial plants normally bloom during the second growing season after seed germination. Many biennials produce a low ring of leaves (called a rosette) during the first season. The plant sends up a leafy shoot, bearing flowers and seeds, during the second season. Many garden plants are biennials, including beet, celery, cabbage, carrot, and turnip. These plants are

usually harvested during the first season, so most gardeners don't see the plants flower. Biennial weeds include wild carrot and curly dock.

### 3-10. PERENNIAL PLANTS

Perennial plants live from year to year, and do not die after once flowering. Perennial plants may produce woody tissue (trees, shrubs, and vines) or may be herbaceous. Aboveground parts of herbaceous perennials may die back during winter, but the plant regrows from persistent underground roots or stems.

### 3-11. ANNUALS AND PERENNIALS

Distinctions between annual and perennial plants are sharper in temperate zones than in the tropics. Plants we consider annuals in temperate climates may live as a perennial in tropical areas.



## Section IV. PHOTOSYNTHESIS

### 3-12. CHEMICAL REACTION

#### a. Definition of Photosynthesis.

Photosynthesis is considered the most important chemical reaction known to man. This reaction is virtually the only process in which inorganic

materials are used to build organic compounds with a resultant storage of energy.

- ◆ Only green plants can carry out photosynthesis.
- ◆ Photosynthesis, the process by which green plants and certain other organisms make food, is a complex series of chemical reactions.
- ◆ This process uses energy from sunlight to make food and oxygen from carbon dioxide and water.
- ◆ The process takes place in the presence of the pigment chlorophyll.
- ◆ We write the overall reaction as follows:



### 3-13. REACTIONS AND INTERMEDIATE PRODUCTS

Photosynthesis actually involves many complex reactions and many intermediate products. A key step in photosynthesis is the fixation of carbon dioxide. Vascular plants use one of three reactions to accomplish this fixation.

a. **Reactions Accomplishing the Fixation of Carbon Dioxide.** These reactions are called the Calvin-Benson cycle (C3), the Hatch/Slack or dicarboxylic acid cycle (C4), and the Crassulacean Acid Metabolism cycle (CAM). Cacti and other xerophytes use the CAM pathway.

- ◆ Temperate zone plants, including cool-season turfgrasses, use the C3 reaction, and tropical turfgrasses, and many weeds, use the C4 reaction.
- ◆ In general, C4 plants are more efficient than C3 plants at fixing carbon dioxide under high temperature and light conditions.

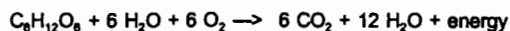
- ♦ A C4 plant, such as bermudagrass, has a competitive advantage over cool-season grasses such as bluegrass, during warm, bright weather.
- ♦ Weeds with a C4 photosynthetic pathway, such as nutsedge, crabgrass, goosegrass, foxtail, and puncturevine have a similar advantage over many turfgrasses.

## Section V. RESPIRATION

### 3-14. THE PROCESS

Living cells use energy to build and maintain protoplasm, membranes, and cell walls. Plants obtain energy from the oxidation of organic compounds.

- ♦ During respiration, plants change sugars such as glucose into simpler substances, and energy is released. Plants store some of the energy released during respiration in the molecule adenosine triphosphate (ATP). Energy is also used for motion (protoplasmic streaming, movement of chromosomes, etc.) and lost as heat.
- ♦ We may represent the overall reaction as follows:



### 3-15. OPPOSITE EFFECT FROM PHOTOSYNTHESIS

Respiration is virtually the opposite of photosynthesis in its overall effect. Photosynthesis uses CO<sub>2</sub>, releases O<sub>2</sub>, and stores energy. Respiration uses O<sub>2</sub>, releases CO<sub>2</sub> and releases energy. Under adequate light conditions, photosynthesis proceeds at a rate five

or ten times more rapidly than respiration, so plant metabolism results in a net gain of oxygen and stored energy.

## PHOTOSYNTHESIS and RESPIRATION

- ♦ Photosynthesis:
  - Uses carbon dioxide.
  - Releases oxygen.
  - Stores energy.
- ♦ Respiration:
  - Uses oxygen.
  - Releases carbon dioxide.
  - Releases energy.

## Section VI. TRANSLOCATION

### 3-16. DEFINITION

Translocation is the term applied to all movement of foods, water, and mineral salts within plants.

- ♦ Most of us, without considering the mechanisms of translocation, realize materials do move through the plant body.
- ♦ Even casual observers notice the recovery of wilted plants after watering.
- ♦ Likewise, most people notice a deeper green color and increased plant growth following fertilization of lawn and garden plants.
- ♦ We recognize that water and plant nutrients must have moved into the plant to cause such changes.

### 3-17. WATER MOVEMENT

Water moves through xylem cells, which form the woody stems of trees and shrubs. Trees usually move water through the outer rings of sapwood.

- ♦ We see this demonstrated in hollow trees which have lost the center of the tree trunk, but have not lost the ability to conduct water.
- ♦ Likewise, a bark-girdled tree does not wilt because water movement takes place in xylem tissue beneath the bark. Plants vary in rate of water movement—from several meters per hour in some deciduous trees to one meter or less per hour in conifers.

### 3-18. FOOD AND MINERAL SALT MOVEMENT

Plants move food and mineral salts through phloem tissue. Botanists locate this tissue in the inner bark of trees and in vascular bundles within the stems of monocotyledons (such as grass). Plants usually translocate carbohydrates in the form of sucrose. Organic nitrogen is translocated as amino acids and soluble proteins.

- ♦ Botanists believe translocation usually involves the mechanism of active transport because translocation may be hundreds of times faster than the laws of diffusion permit, and translocation may occur against a diffusion gradient.

### 3-19. GIRDLING

Foresters and farmers sometimes use a technique called girdling to control unwanted trees.

- ♦ They girdle trees by removing a horizontal ring of bark, cutting down to the woody stem.
- ♦ Girdling kills the trees by preventing food from reaching the root system.

- ♦ An observer will notice the cambium above the girdle continues to grow for a while, but the stem below the girdle stops growing immediately.
- ♦ Early colonists in America used the girdling technique to clear land.
- ♦ Untrained grounds maintenance personnel may inadvertently girdle trees by careless use of mowers and weed-eaters.

## Section VII. PLANT GROWTH FACTORS

### 3-20. INFORMATION

Most of us realize plant growth may be affected by a number of environmental factors. Home gardeners soon realize plant growth and survival depend on adequate supply of water, soil nutrients, and light. In this section, we will list a few of the hundreds of plant growth factors.

### 3-21. WATER

Water is necessary for all plant life, and is involved in virtually all plant life processes.

- ♦ Soil nutrients must be dissolved in water to be taken up by roots.
- ♦ Water carries dissolved nutrients to leaves and sugars to the roots.
- ♦ Water is necessary for photosynthesis.

### 3-22. SOIL

Soil is the anchor for plant roots, supplying many of the requirements for plant growth and development. Plant growth is influenced by the chemical and physical condition of the soil.

- ♦ Chemical conditions include availability of nutrients, availability of toxins (such as aluminum), pH, soil gases, etc.
- ♦ Physical conditions include texture, pore space, organic matter content, moisture content, and compaction.

### 3-23. TEMPERATURE

Temperature is a factor which influences all plant activities. Most plant growth occurs within fairly narrow temperature limits. Specifically, temperature affects water absorption, transpiration (loss of water vapor from leaves), respiration, and cell division.

### 3-24. LIGHT

Light is the energy source driving photosynthesis. Plants respond to light intensity, duration, and wavelength.

- ♦ Photosynthesis rates usually increase until one third of full sunlight is reached.
- ♦ Plants growing in full sunlight are thicker, smaller, have less leaf surface, and thicker leaf cuticles than plants grown in partial shade.
- ♦ Plants growing in partial shade are larger, taller, have more leaf surface, and are less tolerant of traffic than plants grown in full sun.



## EXERCISES, LESSON 3

**REQUIREMENT.** The following exercises are to be answered by completing the incomplete statement or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

1. Plants of the class \_\_\_\_\_ have an embryo with two seed leaves.
2. Orchids, lilies, pineapples, and herbs are part of the plant class \_\_\_\_\_.
3. The entire life cycle of an \_\_\_\_\_ plant takes only one growing season.
4. Cabbages, celery, and carrots are part of the \_\_\_\_\_ plant class. These plants produce a rosette during the first growth season with flowers and seeds during the second growth season.
5. List the three photosynthetic pathways found in plants.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
6. Under high temperature and good light conditions, which plants are more efficient at fixing carbon dioxide—C4 plants or C3 plants?
 

\_\_\_\_\_
7. The term applied to all movement of foods, water, and mineral salts within plants is
 

\_\_\_\_\_

8. List three reasons water is a factor in plant growth, actually necessary for all plant life.

a. \_\_\_\_\_

b. \_\_\_\_\_

c. \_\_\_\_\_

9. As a plant growth factor, what part does light play in photosynthesis? \_\_\_\_\_

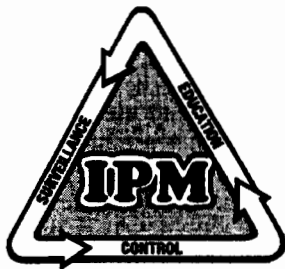
\_\_\_\_\_

10. Fill in the blank with either "X for plants growing in full sunlight" or "Y for plants growing in partial shade."

a. \_\_\_\_\_ are larger, taller, have more leaf surface, and are less tolerant of traffic than \_\_\_\_\_.

b. \_\_\_\_\_ are thicker, smaller, have less leaf surface, and thicker leaf cuticles than \_\_\_\_\_.

**END OF LESSON EXERCISES**



## LESSON ASSIGNMENT

<b>LESSON 4</b>	--	Herbicides.
<b>LESSON ASSIGNMENT</b>	--	Paragraphs 4-1 through 4-39.
<b>TERMINAL LEARNING OBJECTIVE</b>	--	Information gained in this lesson should enable you to safely and effectively use herbicides to control unwanted vegetation as part of an Integrated Pest Management program.
<b>SPECIFIC LESSON OBJECTIVES</b>	--	<p>After completing this lesson, you should be able to:</p> <p>4-1. Define the following terms:</p> <ul style="list-style-type: none"><li>◆ Selective herbicide.</li><li>◆ Contact herbicide.</li><li>◆ Systemic herbicide.</li><li>◆ Soil fumigant.</li><li>◆ Pre-emergent herbicide.</li><li>◆ Post-emergent herbicide.</li><li>◆ Non-selective herbicide.</li><li>◆ Soil sterilant.</li><li>◆ Persistent.</li><li>◆ Leaching.</li></ul> <p>4-2. Identify the characteristics of these herbicide groups:</p> <ul style="list-style-type: none"><li>◆ Growth regulators.</li><li>◆ Photosynthetic inhibitors.</li><li>◆ Amino acid inhibitors (nonpersistent).</li><li>◆ Amino acid inhibitors (persistent).</li><li>◆ Mitotic inhibitors.</li><li>◆ Break up cell wall lining.</li><li>◆ Inhibit bud development.</li><li>◆ Pigment inhibitor.</li><li>◆ Grass specific herbicides.</li><li>◆ Unknown activity.</li></ul> <p>4-3. Identify some of the general problems associated with herbicide application.</p> <p>4-4. Develop a herbicide use strategy for a hypothetical weed control situation.</p>
<b>SUGGESTION</b>	--	After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 4

### HERBICIDES

#### Section I. HISTORY

##### 4-1. EARLY HERBICIDES

Herbicides are pesticides which kill plants. Early farmers knew very well that some substances killed plants. According to legend, the victorious Roman army sowed the fields around Carthage with salt following the Punic Wars, knowing the salt would kill any crops planted in the soil for many years.

##### 4-2. MODERN CONTROLS AND THE ENVIRONMENT

Plant managers in modern times have used kerosene, diesel fuel, sulfuric acid, formaldehyde, used motor oil, sodium arsenite, and a host of other environmentally hazardous chemicals to control unwanted plants. Any of these chemicals will control weeds. Unfortunately, these early weed killers are dangerous to human health and the environment, and they cannot be used without killing all the plants in the area of application.

##### 4-3. HERBICIDE 2,4-D

The modern era of herbicide use began in the early 1940's. Researchers working with the plant growth hormone auxin found a structurally similar chemical with herbicidal characteristics. This herbicide, 2,4-D, was the first selective herbicide.

#### Section II. TERMINOLOGY

##### 4-4. SELECTIVE

Herbicides which kill some plant groups while leaving other groups unharmed are called selective. Selectivity can occur because some plants have an ability to

resist the herbicide effect. Selectivity may also be achieved by correctly timing herbicide applications (while desirable plants are dormant), varying the rate of application, or using a method of application which keeps the herbicide away from susceptible plants. Herbicides which do not affect grasses include clopyralid, 2,4-D, dicamba, picloram, and triclopyr. Herbicides affecting only grasses include Fusilade<sup>R</sup>, Poast<sup>R</sup> and dalapon. It's important to remember selectivity is not total; at some dose rate, even selective herbicides will kill most plants.

##### 4-5. NONSELECTIVE

Nonselective herbicides will kill most groups of plants. These chemicals are used where complete control or bare ground is desired. Herbicides which can be used for nonselective weed control include bromocil, amitrole, imazapyr, glyphosate (Roundup<sup>R</sup>), and sulfometuron methyl. Some of these chemicals will show selectivity at lower rates, and chemicals such as Roundup<sup>R</sup> may be used selectively by planning the timing or method of application to protect desirable plants.

##### 4-6. SOIL STERILANT

Nonselective, persistent herbicides which make the soil incapable of supporting plant growth are called soil sterilants. We use these chemicals in industrial sites, tank farms, electrical sub-stations, and other areas where no vegetation is permitted. An example of a soil sterilant is bromocil.

##### 4-7. SOIL FUMIGANT

Pesticides which vaporize on release and must be contained or confined to the soil are called soil fumigants. These pesticides usually kill any organism in the soil, including most weed seeds. Soil fumigants dissipate quickly after release from the soil, and their effect is temporary. Examples include methyl bromide and pramitol. Soil sterilants may persist for more than three years, particularly in cool, dry soils.

##### 4-8. SYSTEMIC

Systemic (also called translocated) herbicides move throughout the plant after application, whether they are applied to the

foliage or roots. A systemic herbicide can kill the entire plant even though complete herbicide coverage did not occur. Most modern herbicides are systemic. Examples of systemic herbicides include Roundup<sup>R</sup>, 2,4-D, and picloram.

#### 4-9. CONTACT

Contact herbicides kill only the green portion of plants they contact. The herbicide does not move within the plant. These chemicals destroy plant tissue so quickly the plant cannot absorb or translocate the herbicide. Examples of contact herbicides include paraquat, diquat, and fosamine ammonium.

#### 4-10. PREEMERGENT

Preemergent (root-absorbed) herbicides are applied before weeds have sprouted. The chemical is absorbed by the seedling plant root, and the sprouting weed seed is killed before the weeds are even noticed. Industry experts believe preemergent herbicides produce three times more weed control than equal amounts of foliage applied herbicides. However, preemergent herbicides cannot control established weeds. Examples of preemergent herbicides include pendamethalin, atrazine, and simazine.

#### 4-11. POSTEMERGENT

Postemergent (foliage applied) herbicides are applied after weeds are up and growing. These herbicides are absorbed by plant leaves (or sometimes roots). Postemergent herbicides can be used against established weeds. Examples of postemergent herbicides include diquat, Roundup<sup>R</sup>, fosamine ammonium, and imazapyr.

#### 4-12. PERSISTENT

Persistent herbicides remain active in the environment (usually the soil) for long periods of time. Herbicides show a wide range of persistence, and this characteristic is affected by soil type and climate. Persistence is necessary when long-term weed control is desired, but persistent herbicides may hinder the growth of desirable plants. Examples of persistent herbicides include bromocil, pramitol, and picloram.

#### 4-13. LEACHING

Herbicides vary widely in the tendency to move in the soil. This characteristic depends upon the water solubility of the herbicide, the amount applied, the climate (particularly rainfall), and the soil type. Herbicides with relatively high movement in soil include dicamba, bromacil, 2,4-D, and picloram. Herbicides with little or no movement in soil include diquat, Roundup<sup>R</sup> and Surflan<sup>R</sup>. Herbicides which degrade rapidly upon exposure to soil include Krenite<sup>R</sup> and the growth regulator Embark<sup>R</sup>.

### Section III. HERBICIDE CHARACTERISTICS

#### 4-14. GROWTH REGULATORS

These herbicides are chemically similar to natural plant growth hormones, but more active and applied at much higher rates than plants can produce. The distorted growth caused by these herbicides prevents food from reaching the roots, and the plant starves to death. Growth regulator herbicides are translocated and usually leachable in soil. These herbicides are active at very low rates (for example, picloram is applied at one or two pints per acre), so careful application is essential. Examples of growth regulator herbicides include 2,4-D, picloram, clopyralid, and triclopyr.

#### 4-15. PHOTOSYNTHETIC INHIBITORS

These herbicides stop photosynthesis in susceptible plants. Plants cannot manufacture food and die quickly. Photosynthetic inhibitors are usually persistent in soil and not leachable (with the exception of bromocil). Plants absorb the herbicide through the root system or the foliage. Examples include bromocil, atrazine, and hexazinone.

#### 4-16. AMINO ACID INHIBITORS (NONPERSISTENT)

These chemicals prevent the plant from making certain amino acids. The plant cannot manufacture a protein or enzyme necessary to

metabolism and eventually dies. These herbicides have no soil activity and are absorbed only by foliage. Most are nonselective. None of these chemicals persist more than a few days in the environment. Roundup<sup>R</sup> is the best example of such herbicides.

#### **4-17. AMINO ACID INHIBITORS (PERSISTENT)**

Amino acid inhibitors (persistent) also prevent plants from making certain amino acids, but the chemical has residual soil activity. The herbicide may be absorbed by foliage or roots, but foliage absorption is more effective. This group includes some of our most effective herbicides. Examples include imazapyr (Arsenal<sup>R</sup>), sulfometuron methyl (Oust<sup>R</sup>), and chlorsulfuron. These herbicides are generally nonselective, but many grasses resist chlorsulfuron.

#### **4-18. MITOTIC INHIBITORS**

Mitotic inhibitors prevent cell division, thus stopping the growth of roots and shoots of germinating seeds or small seedlings. These herbicides are used for preemergent control and very seldom control established weeds. The herbicide moves upward only in plants, if at all. These chemicals do not usually leach in soil (leaching out of the top 1/2 inch of soil would vastly reduce effectiveness, since most weed seeds are in this soil region). Most mitotic inhibitors are almost water insoluble. This group is very selective. Examples include Surflan<sup>R</sup> and pendimethalin (Stomp<sup>R</sup>).

#### **4-19. CELL WALL LINING BREAK UP**

Herbicides in this group are very water soluble and enter plant leaves very rapidly (within 30 minutes). The chemicals damage the lining of the cell walls, allowing cell contents to leak out. Leaves appear water-soaked. Plants are killed very quickly (in hours). These herbicides are tied up immediately by soil particles, so there is no soil activity. Paraquat and diquat are the best examples of these contact herbicides. Paraquat is widely used as a weed killer and chemical desiccant (when crops must be dried before harvest) in agriculture. No other herbicide kills plants so rapidly, but the chemical is toxic and must be handled carefully. Inhalation of paraquat

could cause permanent damage to lung tissue. Diquat is less hazardous, but still must be carefully handled.

#### **4-20. BUD DEVELOPMENT INHIBITORS**

Fosamine ammonium (Krenite<sup>R</sup>) is a unique herbicide which is applied to woody plants late in the growing season. Susceptible woody plants do not begin to grow the next season, and eventually the treated areas die. The chemical moves only from the leaves to the buds, so complete coverage is necessary. There is no soil activity. Krenite<sup>R</sup> doesn't injure grasses.

#### **4-21. PIGMENT INHIBITORS**

Amizol is an herbicide which prevents color formation in plants. The herbicide destroys all plant pigments, including chlorophyll. The plant cannot produce food or dissipate solar energy. Solar energy strikes the unprotected plant cells and destroys the cell structure. This herbicide is soluble in water and moves throughout the plant after application. New leaves formed by the plant are almost white. Amizol is usually nonselective, but some perennial grasses have resistance. Amizol is a restricted use pesticide.

#### **4-22. GRASS SPECIFIC HERBICIDES**

Most selective herbicides kill broadleaf plants and leave grasses unharmed, but a few herbicides kill only annual and perennial grasses. These herbicides are absorbed by leaves and have little soil activity. The chemicals are used at low rates and applied to foliage. Examples include Poast<sup>R</sup>, and Fusilade<sup>R</sup>.

#### **4-23. UNKNOWN ACTIVITY**

Monosodium methanearsonate (MSMA) is an organic arsenical which is water soluble, inhibits plant growth in general, and causes abnormal cell division. Diclobenil inhibits growing points, both buds and root tips; inhibits seed germination; and does not control weeds which are already established. This herbicide should be mixed into the soil. Weed scientists aren't sure about the specific activity of these chemicals.

## **Section IV. APPLICATION PROBLEMS**

### **4-24. LABELLING**

Herbicides must be labelled for the site of application. Although the plant to be controlled may not appear on the label, the site must be on the label. For example, herbicides used on a golf course must be labelled for turfgrass sites. Herbicides used to control aquatic plants must be labelled for aquatic sites. Application to a site not listed on the label is a violation of law.

### **4-25. OBSTRUCTIONS**

Herbicides are applied to outdoor sites, so the applicator must avoid obstructions, including fixed structures, moving automobiles, and especially pedestrians. Application during windy days is risky because off-site pesticide movement is likely.

### **4-26. ACCESSIBILITY**

Actually reaching the treatment area can be a problem during outdoor pesticide applications. Accessibility may be limited by fences, hedgerows and ditches, or by terrain. Sloping terrain is a particular problem because equipment choice is limited (heavy equipment is dangerous on a steep slope), and the herbicide may move laterally during rain.

### **4-27. DITCHES**

Herbicide application around ditches is risky because the ditches carry surface water (and potentially herbicides) after a rain. Herbicides applied improperly into the ditch may end up in a lake or stream, with unforeseeable consequences. The plant species growing in a ditch will be different than plants growing in the surrounding area, so the herbicide may not control plants in the ditch.

### **4-28. LEACHING**

Leaching is a term describing the movement of liquids down through the soil. Leaching herbicides may cause injury to deep-

rooted desirable plants or leave the upper layer of soil unprotected from weeds. Leached herbicides may also enter and contaminate the ground water in certain situations. Groundwater contamination is most likely with a shallow water table and sandy, porous soil. Herbicides may also leach through sandy soils into adjacent wells. The triazine herbicides (Atrazine and Simazine) and the herbicide picloram, among others, are suspected of movement into groundwater. The applicator must be aware of the geology (soil type and water table) in all areas where herbicide is applied.

### **4-29. LATERAL MOVEMENT**

This term describes movement of herbicides across a surface (usually soil) in flowing water. Lateral movement is often the result of soil compaction, water saturated soils, or intense rainfall immediately after application.

### **4-30. BACKFLASH**

Backflash is the uptake of herbicide by trees adjacent to herbicide treated trees. This phenomenon is most common in the forestry industry. Foresters often use herbicides to control unwanted trees in a process called timber stand improvement. The herbicide is absorbed by the treated tree and is translocated throughout the tree. Herbicide can leak from the tree roots or move into another tree through root grafts.

### **4-31. CLIMATE**

Like picnics, herbicide applications can be spoiled by the weather. As a general rule, herbicides should be applied on warm, calm days when no rain is expected. The applicator may have to use special equipment (such as shrouded sprayers) or granular formulations in areas where windy days are the rule. A problem in dry, dusty areas and along roadsides is dirt and dust on plant leaves. The dirt binds with herbicide and prevents absorption by plants.

### **4-32. PLANT FACTORS**

Herbicides are land management tools, so the applicator must carefully consider the management plans for a land area before applying a herbicide.

a. **No Vegetation to Release.** For example, herbicides are often used to "release" desirable plants (such as turfgrass) from competition with weeds. After weeds have been killed, the applicator sometimes finds the desirable plant was never present. Homeowners often kill the crabgrass in their lawn, only to find crabgrass was their lawn.

b. **Weed Invasion.** It's also useful to remember that no herbicide application lasts forever. Weeds recolonize an area of bare soil after the herbicide breaks down. In addition, bare soil erodes. If a nonselective herbicide is used, planting with desirable plants should immediately follow (the exception being electrical substations and other areas where no vegetation is permitted).

c. **Plant Size.** Larger weeds require more herbicide. The applicator must look at the label to see if the dose should be increased for taller weeds. Herbicides like Roundup<sup>®</sup> specify a larger dose for weeds over six inches high.

#### 4-33. TIMING

It's essential to properly time herbicide applications. Plants are most vulnerable to herbicides as seedlings and young, actively growing plants.

- ◆ Once a plant begins the reproductive stage or moves into the "maturity" stage after seeds have been set, herbicides are much less effective.
- ◆ In fact, annual plants die soon after seeds are set, making herbicide application superfluous.
- ◆ Preemergent herbicides must be applied before weed seeds have sprouted.
- ◆ Postemergent herbicides must be applied early in the growing season.
- ◆ Late season application is generally useless (although exceptions exist).

#### 4-34. LAYERED VEGETATION

Foresters and roadside vegetation managers often encounter a tangle of plants of various sizes and heights. The herbicide is usually effective against the tallest plants, less effective against shorter plants, and completely ineffective against plants growing at ground level. Controlling layered vegetation may require special equipment (high pressure sprayers) or special formulations (large, heavy granules of a soil-active herbicide).

#### 4-35. ENVIRONMENTAL CONCERNS

Herbicide applicators must keep the following environmental issues in mind during every operation.

- ◆ Spills and damage to nontarget plants.
- ◆ Drift meaning the movement of herbicide off target due to wind.

**NOTE:** Stop the herbicide application if the application cannot be confined to the target area.

- ◆ Threatened or endangered species.
- ◆ Danger to ground water.

#### APPLICATION PROBLEMS

- ◆ Labelling.
- ◆ Obstructions.
- ◆ Accessibility.
- ◆ Ditches.
- ◆ Leaching.
- ◆ Lateral movement.
- ◆ Backflash.
- ◆ Climate.
- ◆ Plant factors.
- ◆ Timing.
- ◆ Layered vegetation.
- ◆ Environmental concerns.

**Section V. HERBICIDE USE  
STRATEGIES**

**4-36. PRECAUTIONS**

Before any herbicide application, survey the area and consider the possibility of damaging ornamentals or other desirable plants.

- ◆ The area should usually be cleared of other personnel, pets, and valuable property.
- ◆ The applicator should placard the area with warning signs after the application is complete.
- ◆ The applicator should carefully review the label and ensure all safety equipment is on hand.
- ◆ Herbicide should not normally be applied on rainy, windy, or cold days.

**4-37. ANNUAL GRASSES**

Control annual grasses with preemergence herbicides such as pendimethalin or Surflan<sup>®</sup>. The herbicide must reach thatch or soil level. Dethatch the turf before application, and water in herbicide. Do not apply preemergents before or soon after seeding with turfgrass.

**4-38. BROADLEAF WEEDS**

Control broadleaf weeds with selective, systemic herbicides applied to foliage. Apply the herbicide when plants are young and actively growing. Avoid applying when rain is expected. Avoid mowing for three days after application. Don't herbicide newly seeded or sodded areas; these areas are chemically sensitive.

**4-39. PERENNIAL GRASSES**

Control perennial grasses with spot treatments of selective or non-selective herbicide. It's nearly impossible to selectively remove these persistent weeds, so broadcast treatments are often unsuccessful. A heavy spot treatment will kill the perennial grass and the area can be replanted.

#### EXERCISES, LESSON 4

**REQUIREMENT.** The following exercises are to be answered by selecting the correct letter, completing the incomplete statement, or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

**Match the herbicide term in Column A with the correct definition in Column B.  
(Write the correct letter in the space next to the Column A number.)**

Column A	Column B
___ 1. Selective	a. Herbicides which are applied before weeds sprout.
___ 2. Nonselective	b. Herbicides which kill some plant groups but leave others unharmed.
___ 3. Soil sterilant	c. Herbicides which may cause injury to deep-rooted, desirable plants or which may leave the upper layer of soil unprotected from weeds.
___ 4. Soil fumigant	d. Herbicides which kill only the green portion of plants the herbicide contacts.
___ 5. Preemergent	e. Herbicides which remain active in the environment for long periods of time.
___ 6. Postemergent	f. Herbicides which kill most plant groups.
___ 7. Contact	g. Herbicides which vaporize on release and must be contained or confined to the soil.
___ 8. Systemic	h. Herbicides which move throughout the plant after application, whether applied to the foliage or roots.
___ 9. Persistent	i. Herbicides which make the soil incapable of supporting plant growth.
___ 10. Leaching	j. Herbicides which are applied after weeds are up and growing.

11. Bromocil, atrazine, and hexazinone are examples of herbicides classed as \_\_\_\_\_. Herbicides in this group are absorbed through the foliage or root system of the plants. This herbicide prevents plants from manufacturing food, and the plants dies.

12. Why is off-site pesticide application risky on windy days? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

13. The best climatic conditions for the application of pesticides are \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

14. Controlling \_\_\_\_\_ involves following these guidelines:

- ◆ Using selective herbicides applied to foliage.
- ◆ Applying herbicides when plants are young and actively growing.
- ◆ Avoiding mowing for three days after herbicide application.
- ◆ Refraining from using herbicide on newly seeded or sodded areas.

**END OF LESSON EXERCISES**



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## LESSON ASSIGNMENT

<b>LESSON 5</b>	--	Turfgrass Insects.
<b>LESSON ASSIGNMENT</b>	--	Paragraphs 5-1 through 5-23.
<b>TERMINAL LEARNING OBJECTIVE</b>	--	Information gained in this lesson should enable you to identify and manage turfgrass insects using the principles of integrated pest management.
<b>SPECIFIC LESSON OBJECTIVES</b>	--	After completing this lesson, you should be able to:  5-1. Identify the control measures which would be most effective against each of the following turf pests: <ul style="list-style-type: none"><li>♦ Fall armyworms.</li><li>♦ Sod webworms.</li><li>♦ Cutworms.</li><li>♦ Grasshoppers.</li><li>♦ White grubs.</li><li>♦ Coleopteran pests: billbugs.</li><li>♦ Mole crickets.</li><li>♦ Red imported fire ants.</li><li>♦ Chinch bugs.</li><li>♦ Ground pearls.</li><li>♦ Two-lived spittlebugs.</li><li>♦ Greenbugs.</li></ul> 5-2. Identify the environmental issues which should be considered when applying pesticides to turf areas.
<b>SUGGESTION</b>	--	After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 5

### TURFGRASS INSECTS

#### Section I. GENERAL INFORMATION

##### 5-1. INTRODUCTION

Turfgrass is home to a vast number and variety of insects. Some of the insects living in turf only use the grass for shelter; this group includes fleas, which live in the grass but do not

feed on grasses at all. Other insects use grass for food. These insects can destroy the appearance of a lawn or actually kill the grass when they occur in sufficient numbers.

##### 5-2. TURFGRASS MANAGEMENT AND ITS RESULTS

Turfgrasses are very intensively managed plants. Even the most careless homeowner probably waters and fertilizes his lawn occasionally, and mows it every weekend. Athletic fields and golf courses are managed at a much higher (critics would say "fanatic") level of

maintenance. Unfortunately, the constant inputs of fertilizer and water produce a plant which is high in nutrients; good food for foraging insects. Constant mowing forces turfgrass to produce new plant tissue every few days; the soft plant tissue is favored by plant feeding insects.

### 5-3. INSECT CONTROL AND TURFGRASS

In many arid regions, the golf course is the only green spot and the only spot where insects can feed for miles around. Because so many insects, with so much destructive capability, are adapted to feed on turfgrass, insect control is a big part of turf management. It's impossible to discuss all of the insects which attack turf. This lesson will discuss some of the most important and widespread turf feeding insects.

## Section II. DEFOLIATORS

### 5-4. FALL ARMYWORM

The fall armyworm is an insect which chews the stems and blades of turfgrass.

- ◆ The larval stage does all the feeding and all the turf damage. Larvae are dark green with several light stripes along the body and an inverted "Y" on the front of the head.
- ◆ The fall armyworm feeds on a wide variety of plants, skeletonizing leaves and severing grass blades above the ground.
- ◆ This insect infests in hordes.
- ◆ The fall armyworm is susceptible to cold and cannot overwinter in most of the United States.
  - Adult moths migrate northward every spring and lay eggs.
- ◆ The larvae emerge in late spring or summer.

### 5-5. SOD WEBWORM

a. **Identification.** The sod webworm feeds on grass leaves and stems. The larva is grayish-tan and only 1/4 to 3/4 inch long with four rows of dark brown spots and a dark head. The adult is a grayish-white moth which flies in zigzag patterns over lawns in early evening or when flushed by disturbances. The larvae feed at the soil line, leaving jagged edges on grass leaves. The sod webworm builds a silken web, or retreat, at the soil level. Larvae feed at night and move into the silk-lined retreat during the day.

b. **Damage.** Damage appears as irregular areas of dead grass. Larvae chew grass blades, often severing the grass crown and leaving softball size holes in the turf. Sometimes the small patches of dead grass coalesce into large sections of damaged turf. Sod webworm damage may look like fungal damage.

### 5-6. CUTWORM

Cutworms are another lepidopteran (moths and butterflies) pest of turfgrass. The larvae are inconspicuous, dull-colored caterpillars with nocturnal feeding habits. The caterpillar likes to hide below the ground during daylight hours and emerge at night to feed on any green plant. The adult is a nondescript brown moth. Cutworms sever young plants at ground level. These insects attack a wide range of plants.

### 5-7. GRASSHOPPERS

Grasshoppers are voracious feeders in any life stage. These insects very seldom cause extensive damage to turfgrass except when huge populations occur and feed on anything green. Since these large grasshopper populations are migratory, control is seldom effective.

### 5-8. CONTROL MEASURES FOR DEFOLIATORS

Defoliating insects--fall armyworms, sod webworms, cutworms, and grasshoppers--are difficult to control without chemical insecticides. The key to successful control is placing the insecticide on turfgrass leaves, so the feeding larvae will ingest a lethal dose.

- ♦ Fall armyworms and cutworms feed on the upper stems and leaves, so a registered insecticide should be applied with very little water (just enough for even distribution) and a sticker-spreader added to the spray.
  - The sticker-spreader causes the spray to adhere to grass leaves.
- ♦ Sod webworms live and feed in the lower part of the grass plant, so the insecticide should be applied with plenty of water and no sticker-spreader.
- ♦ To facilitate penetration of the insecticide, it's a good practice to remove thatch by vertical mowing before applying the insecticide.
- ♦ Surveillance for sod webworm larvae should begin about 10 days after female moths are sighted.

### Section III. ROOT CHEWING INSECTS

#### 5-9. WHITE GRUBS

**a. Identification.** White grubs are really the larvae of various scarab beetles, including green June beetles, masked chafers, European chafers, Oriental beetles, May beetles, Japanese beetles, and black turfgrass ataenius. The larvae are "u" or "c" shaped, cream colored, with three pairs of legs.

**b. Damage.** White grubs devour roots near soil surface, causing plants to wilt shortly after watering. This larval root pruning can quickly kill turf during dry weather. Damage is especially bad under street lights.

- ♦ Turfgrass feels soft and spongy underfoot during a grub infestation due to root damage.
- ♦ Dead grass may sometimes be rolled up like a carpet.

- ♦ Adult beetles vary in their feeding habits.
  - The adult Japanese beetle feeds on turfgrass foliage, and the foliage and fruit of almost 300 other plants.
  - May and June beetles feed on the foliage of deciduous trees.
  - The masked chafer adult doesn't feed at all.
  - The black turfgrass ataenius adult feeds on decaying organic matter.

**c. Control.** Grub worms are the most difficult of all turfgrass insects to control because of their subterranean habits.

- ♦ Insecticide must be applied to the soil surface and carried into the soil by gravity and water.
- ♦ A layer of thatch, or any restriction to water absorption, will reduce the effectiveness of insecticide application.
- ♦ The applicator should dethatch, aerate, and water the turf before spraying (very dry soil doesn't absorb water quickly).
- ♦ White grubs should be controlled when the grubs are young, actively growing, and close to the soil surface.
- ♦ A properly labeled insecticide should be applied in plenty of water and watered into the soil.

#### TURFGRASS DEFOLIATORS

- ♦ Fall armyworms.
- ♦ Sod webworms.
- ♦ Cutworms.
- ♦ Grasshoppers.

## 5-10. COLEOPTERAN PESTS: BILLBUGS

**a. Identification.** The bluegrass billbug and hunting billbug are small snout beetles, 7 to 11 mm in length. Most adult billbugs are black, brown, or gray. The larvae are white, legless (in contrast to white grubs) insects with a brown head capsule. The last instar larvae are 7 to 10 mm long. Larvae are found in the turf crown or in the shallow roots just below the thatch layer.

**b. Damage.** The bluegrass billbug is a pest of cool season grasses. The hunting billbug attacks zoysiagrass, bermudagrass, and sometimes St. Augustine grass.

- ◆ Adult billbugs feed on turfgrass crowns, stems, and new leaf buds.
- ◆ The larvae feed within the stems, crown, and the shallow roots.
- ◆ The turf remains firm underfoot during billbug infestations.
- ◆ Damage shows up as irregular elongated or rounded areas of brown and dying grass.
- ◆ Damage is greater during extended periods of dry weather.

**c. Control.** Billbug larvae and adults feed in the crown area of the turf or in the shallow roots. The insecticide should be applied with plenty of water, after thatch has been removed. Apply insecticide in early summer before the adults have laid eggs.

## 5-11. MOLE CRICKETS

**a. Identification.** Mole crickets are large, brownish crickets, averaging 3.2 cm in length and 1 cm wide. These crickets are well adapted for digging.

- ◆ They have strong shovel-like forelegs and a greatly enlarged, heavily chitinized prothorax for shaping and packing soil in tunnels.

- ◆ The forewings overlap and are shorter than the abdomen.
- ◆ There are two species of mole cricket in the United States: the Southern mole cricket and the tawny mole cricket. Neither of these species is native to the United States. They probably originated in South America.

**b. Damage.** Mole crickets damage all of the warm season turfgrasses, but bahiagrass and bermudagrass are most severely damaged. Mole crickets are only found in light, sandy soils.

- ◆ Mole crickets feed directly on the grass root system and burrow in the upper soil. The burrowing dislodges roots and dries out the soil.
- ◆ Turf feels spongy underfoot because of the extensive tunneling. A population of one mole cricket per square foot has been found sufficient to destroy a golf course tee overnight. Most damage occurs during late summer and early fall when nymphs are actively foraging for food.

**c. Control.** These insects are difficult to control. Mole crickets live in tunnels in the soil, so reaching the insect with a lethal dose of pesticide is difficult.

- ◆ Dethatch the turf to facilitate penetration of the insecticide.
- ◆ The applicator should apply a registered insecticide in plenty of water, then water and roll the turf after application.
- ◆ Applying fertilizer may stimulate the remaining grass to cover damaged spots.
- ◆ Parasitic nematodes have been released to feed on the crickets in some situations.
  - Nematodes usually reduce the population, but do not eradicate mole crickets.

## 5-12. RED IMPORTED FIRE ANT

**a. Identification.** The red imported fire ant is a fairly large ant, 11 mm long with a red head and thorax and black abdomen. The ants build mounds of various sizes, but a typical mound is 14 inches in diameter and 8 to 10 inches high. Mound height is greater in high clay soils or after heavy rains (the ants build a higher mound to escape rising soil water).

**b. Damage.** Imported red fire ants don't actually feed on grasses.

- ◆ Damage results from mound building. The mounds smother grass, and the underground galleries beneath the mound dry the soil and thin out grass stands.
- ◆ Imported red fire ants kill wildlife, particularly ground nesting birds and small animals, but even white-tailed deer fawns have been killed by the ants.
- ◆ The ant's vicious sting may cause human injury or death.

**c. Control.** Ants are social insects, with a reproductive "queen" (or queens) and thousands of sterile workers in each colony. Killing any number of workers will accomplish nothing, because the queen produces more workers every day. Killing the reproductive queen destroys the colony.

- ◆ Baits are probably the most cost-effective way to kill ant colonies.
  - The bait is a low-toxicity pesticide (so workers will be able to feed the bait to the queen before dying).
  - Some baits aren't poisons at all, but growth regulators which destroy the queen's reproductive capability.
  - Apply baits at low levels (about one pound per acre) every six months.

- ◆ We may also kill red imported fire ants by injecting or drenching a mound with a registered insecticide.

### **TURFGRASS ROOT- CHEWING INSECTS**

- ◆ White grubs.
- ◆ Billbugs.
- ◆ Mole crickets.
- ◆ Red imported fire ants.

## **Section IV. INSECTS THAT FEED ON PLANT JUICES**

## 5-13. CHINCH BUGS

**a. Identification.** Adult chinch bugs have black bodies, white wings, and a small black triangle in the middle of the outer edge of each wing. Nymphs are red with a white band on the abdomen. The nymphs turn orange, brown, and then black as they mature. Chinch bugs are small insects and difficult to see in the turf grass.

**b. Damage.** Chinch bugs have piercing, sucking mouthparts. They suck the plant sap from the crowns and stems of grasses. Chinch bugs tend to aggregate and cause localized damage. Especially in hot and dry areas, damage appears as a patch of wilted and dead grass. The center of the patch is dead brown, and the margins have a yellowish color.

**c. Control.** Chinch bugs can be controlled with liquid or granular insecticides.

- ◆ Water turf before spraying a liquid, and water turf for one hour after applying granules.

- ◆ Use slow-release fertilizers which are low in nitrogen (high nitrogen levels seem to make turfgrass more susceptible to chinch bugs).

#### 5-14. GROUND PEARLS

**a. Identification.** Ground pearls are scale insects. The adult females are wingless, pinkish scale insects about 1.6 mm long. Males are rare and gnatlike, ranging in size from 1 mm to 8 mm in length. The nymphs have a hard, globular, yellowish-purple shell. These cysts are usually 0.5 to 2.0 mm in diameter. The nymph has sucking mouthparts which extend through the wall of the cyst and are inserted into grass roots.

**b. Damage.** Ground pearls attack warm season grasses including St. Augustine, zoysia, bermuda, and centipede. During dry weather, the grass yellows and browns, often dying by fall. Damage appears as irregular patches.

**c. Control.** No practical treatment is now available. Turfgrass should be fertilized and irrigated for maximum growth.

#### 5-15. TWO-LINED SPITTLEBUG

**a. Identification.** The two-lined spittlebug is easily recognizable as a black insect with red eyes and legs, and two red or orange lines across the wings. The insect is 6 to 10 mm long. Nymphs resemble small adults. Yellow, orange, or white insects with red eyes and brown heads, the nymphs are enveloped in white froth which resembles spittle.

**b. Damage.** Two-lined spittlebugs attack bermuda, St. Augustine, centipede, and ryegrasses. Adults and nymphs pierce plant tissues and feed on sap. Grass withers and stops growing.

**c. Control.** The two-lined spittlebug feeds in turfgrass foliage. The key to control is placing a properly labeled insecticide in the foliage so the spittlebug will ingest a lethal dose. Apply the insecticide with a sticker spreader and just enough water to obtain an even distribution.

#### 5-16. GREENBUGS

**a. Identification.** Greenbugs are in the aphid family. These insects feed on small grains and turfgrass. Adults are soft bodied, pear-shaped insects 1.5 to 2.5 mm long, pale yellow to light green with a dark green dorsal median stripe. Both winged and wingless adult forms occur. Nymphs resemble wingless adults.

**b. Damage.** Greenbugs attack cool season grasses. Adults and nymphs pierce grass blades with mouthparts and feed on phloem tissue.

- ◆ The toxic salivary secretions of the greenbugs cause yellow spots and tissue death.
- ◆ Damage begins in shaded areas in the form of circular or irregular brown patches.
- ◆ Damaged turf may be a burnt orange.

**c. Control.** Greenbugs are easily killed with an application of a labeled insecticide or an insecticidal soap during May or June. It's risky to use insecticidal soap in late June or July because the hot sun may kill grass after an application of soapy water. Natural predators and parasites often effect control of greenbugs. Wasps and ladybugs are very effective against this pest.

#### **TURFGRASS PLANT JUICE-FEEDING INSECTS**

- ◆ Chinch bugs.
- ◆ Ground pearls.
- ◆ Two-lined spittle bugs.
- ◆ Greenbugs.

## Section V. MONITORING

### 5-17. CHINCH BUGS

Flood the sod in a small area to cause chinch bugs to float up or climb grass stems. Using a can with both ends cut out, insert the can into turf where grass is yellowed and declining. Wait five minutes for chinch bugs to float to the top of the water. Part grass in yellowed areas and look for chinch bugs.

### 5-18. SOD WEBWORMS AND OTHER LAWN CATERPILLARS

Mix 1.5 ounces of dishwashing soap in two gallons of water and drench four square foot area. Insects will emerge to the soil surface if present.

### 5-19. MOLE CRICKETS

The same monitoring technique used for lawn caterpillars will work for mole crickets.

### 5-20. BILLBUGS AND WHITE GRUBS

Cut three sides of a one square foot piece of sod to a depth of two inches. Lay back the sod and examine roots and soil. If you count three to four grubs per square foot, treat with insecticide.

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## Section VI. GENERAL CONTROL TECHNIQUES

### 5-21. TURF MANAGEMENT

The severity and frequency of turfgrass insect infestations may be reduced by proper management. The following cultural practices are an important part of an integrated pest management program for turfgrass insects:

- ◆ Resistant cultivars.
- ◆ Proper mowing.

- ◆ Soil moisture control.
- ◆ Thatch control.
- ◆ Avoid excessive nitrogen.
- ◆ Use slow-release fertilizer.

### 5-22. ENVIRONMENTAL CONSIDERATIONS

Outdoor insecticide applications are inherently risky. The applicator should observe the following precautions during all insecticide applications:

- ◆ Avoid drift.
- ◆ Use precautions on slopes to prevent run-off (possibly reducing spray volume).
- ◆ Beware of possibility for groundwater contamination (only a concern with high water tables and sandy soils).
- ◆ Avoid persistent insecticides.
- ◆ Beware of nontarget organisms.
- ◆ Consider heavy rain--don't treat if rain is imminent.
- ◆ Keep domestic animals and people off the treatment area.

### 5-23. CLOSING

Turfgrass management is an important part of the world in which we live, aesthetically and as part of the cycle of energy and life. In our efforts to manage the various insects that find turfgrass appealing, we must ensure that we protect the environment which is so essential to life.

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## EXERCISES, LESSON 5

**REQUIREMENT.** The following exercises are to be answered by selecting the correct letter, completing the incomplete statement, or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

1. Control of grasshoppers is seldom effective because \_\_\_\_\_

\_\_\_\_\_

2. What is the key to successful control of defoliators such as the fall armyworms, sod webworms, and cutworms? \_\_\_\_\_

\_\_\_\_\_

3. The purpose of a sticker-spreader added to insecticide used in controlling defoliators is \_\_\_\_\_

\_\_\_\_\_

4. Before insecticide is sprayed to control white grubs, the pesticide applicator should:

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

5. What time of year should insecticide to control billbugs be applied? Why?

\_\_\_\_\_

6. a. The most cost-effective way to destroy a red-imported ant colony is to \_\_\_\_\_

\_\_\_\_\_

b. How does this pesticide work?

\_\_\_\_\_

7. List five environmental considerations to be remembered when applying pesticides.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

8. Mixing 1.5 ounces of dishwashing soap in two gallons of water and drenching a four square foot area is a way to monitor \_\_\_\_\_

Webworms, \_\_\_\_\_ caterpillars, and \_\_\_\_\_ crickets.

9. Where chinch bugs are a problem, use fertilizers low in nitrogen because \_\_\_\_\_

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10. What is the key to two-lined spittlebug control? \_\_\_\_\_

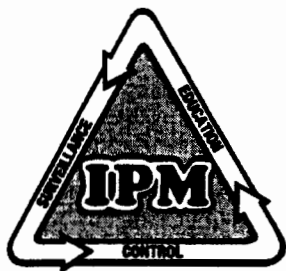
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**END OF LESSON EXERCISES**



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## LESSON ASSIGNMENT

<b>LESSON 6</b>	--	Insects of Trees and Ornamental Plants.
<b>LESSON ASSIGNMENT</b>	--	Paragraphs 6-1 through 6-24.
<b>TERMINAL LEARNING OBJECTIVE</b>	--	Information gained in this lesson should enable you to manage insects of trees and ornamental plants using integrated pest management principles and techniques.
<b>LESSON OBJECTIVES</b>	--	<p>After completing this lesson, you should be able to:</p> <p>6-1. Identify the insects of trees or ornamental plants from a description of the damage caused by the insect.</p> <p>6-2. Identify the control measures which would be most effective against each of the following pests of trees and woody ornamentals:</p> <ul style="list-style-type: none"><li>◆ Fall webworm.</li><li>◆ Eastern tent caterpillar.</li><li>◆ Bagworms.</li><li>◆ Gypsy moth.</li><li>◆ Sawfly.</li><li>◆ Aphid.</li><li>◆ Adelgid.</li><li>◆ Bark beetle.</li><li>◆ Wood borer.</li><li>◆ Scale.</li></ul>
<b>SUGGESTION</b>	--	After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 6

### INSECTS OF TREES AND ORNAMENTALS

#### Section I. INTRODUCTION

#### 6-1. GENERAL INFORMATION

All living plants serve as food for a huge variety of living organisms, including insects. Generally this presents little problem for the pest manager, because landscape plants can coexist

with most plant feeders without suffering harm. For example, a healthy tree can endure the loss of 40 percent of its foliage without being damaged. However, certain insect pests may permanently damage or kill landscape plants.

#### 6-2. INSECTS AND THE ENVIRONMENT

Insect pests should be regarded as part of the total environment in which plants exist. When environmental conditions are too far from the normal range, plants cannot develop normally, and may not survive without human intervention. In this lesson, some of the most common and troublesome of the insects which

feed on landscape plants as well as identification and management of pest species will be discussed.

## Section II. DEFOLIATORS

### 6-3. INFORMATION

Hundreds of insect species attack woody plants in the most direct and obvious way, by simply eating leaves or foliage. These "defoliators" cause damage ranging from slight to catastrophic, depending on the percentage of foliage actually removed. Although healthy plants can easily tolerate partial defoliation, complete defoliation may be lethal. We will discuss a few defoliators common to North America in this section.

#### DEFOLIATORS

- »» Fall webworm.
- »» Eastern tent caterpillar.
- »» Forest tent caterpillar.
- »» Bagworm.
- »» Sawfly.
- »» Gypsy moth.

### 6-4. FALL WEBWORM

Fall webworms range throughout North America, feeding on the leaves of many trees and ornamental shrubs. This North American species has been accidentally introduced to Europe and parts of Asia, where it has become a major pest.

**a. Host Plants.** The fall webworm feeds on most shade trees, fruit trees, and ornamentals, except conifers. In Japan, the fall webworm feeds on at least 317 plants. In North America, the webworm feeds on approximately 88 tree species.

**b. Web Building.** The webworm builds a web at the tip of a branch. The web is expanded over new feeding areas and toward the center of the tree as the colony grows. Larvae feed within the web, never leaving the web until adulthood.

**c. Life Cycle.** Larvae are one inch long full-grown. They are colored pale yellow to green with long, white hairs.

- ♦ The larvae do all the feeding. All of the larvae within a colony will make jerky motions in perfect rhythm when alarmed. The larvae pass through up to 11 instars of development.
- ♦ The adult webworm is a white moth with a one to one-fourth inch wingspan.
- ♦ The adult female lays eggs in white cotton patches on the underside of host plant leaves. Egg laying occurs in March and April.
- ♦ The fall webworm may have several generations per year, depending on the climate. In warm climates, the webworm commonly has four generations per year.

**d. Natural Enemies.** At least 50 parasites and 35 predatory species attack the fall webworm in North America. A similar number of parasites and predators are found in Europe and Asia.

### 6-5. EASTERN TENT CATERPILLAR

This caterpillar is considered the most widespread defoliator in the eastern United States. This insect is apparently native to North America. The tent caterpillar ranges as far west as the Rocky Mountains.

**a. Host Plants.** The Eastern tent caterpillar feeds on wild cherry and related trees such as apple or other trees in the rose family. It also feeds on a variety of hardwood trees when necessary, such as ash, birch, black gum, maple, and oak.

**b. Web Building.** The tent caterpillar builds a web (tent) in a branch fork. The web is expanded as the colony grows. Caterpillars feed outside the web at night. When the larval population is large, the entire tree is covered with webbing, and every leaf is eaten.

**c. Larva.** The larva of the tent caterpillar is about two inches long, full grown, with a straight white line down the back. Larvae hatch in early spring. After reaching full size, the larvae spin white cocoons on tree trunks, fences, or other objects.

**d. Adults.** Adults are reddish-brown moths with two whitish stripes running obliquely across each forewing. The adult moths emerge in late June or early July. The female moth mates and deposits her eggs on twigs. There is only one generation per year.

**e. Reproduction.** The female lays eggs in distinctive shiny, spindle-shaped black masses which encircle small twigs. These masses are up to 19 mm long and contain 150 to 350 eggs. The shiny masses are often noticed by casual observers.

#### **6-6. FOREST TENT CATERPILLAR**

The forest tent caterpillar ranges throughout North America. This insect is closely related to the Eastern tent caterpillar and similar in life, history, and habits.

**a. Host Plants.** The forest tent caterpillar feeds on a number of deciduous trees, but the foliage of ash, birch, black gum, red gum, oak, poplar, and maple is preferred.

**b. Silk Mat.** This insect is somewhat misnamed, because no real tent is built by larvae. The larvae build a silk mat on the trunk or large limbs for resting between feeding periods. Larvae forage in all directions from the silken mat.

**c. Larva.** Each larva is about two inches full-grown, with distinctive white keyhole-shaped spots down the middle of its back and blue lines along the sides (remember the Eastern tent caterpillar has a solid white line down the back).

**d. Reproduction.** The adult is a brown moth which emerges in late June or early July. The female mates and deposits her eggs in a shiny mass which encircles twigs. The egg masses are squared off at the end, in contrast to the spindle shaped masses of Eastern tent caterpillars. There is only one generation per year.

#### **6-7. BAGWORMS**

There are 20 species of bagworms in the United States, but only two or three are economic pests. The bagworm ranges east of the Rocky Mountains, but rarely into the latitudes north of Massachusetts. This insect can be a devastating pest of ornamentals in the South.

**a. Host Plants.** The bagworm feeds on more than 120 trees and shrubs. Bagworms feed principally on arborvitae and juniper in some parts of the United States. The bagworm may also feed on hardwoods such as black locust, maple, buckeye, and boxelder—or conifers such as red cedar, hemlock, and spruce.

**b. Larval Development.** The bagworm is named from the silken "bag" constructed by the larva. The larva makes the bag from silk and bits of leaves. Young larvae feed on the epidermis on the upper side of the leaf with the bag pointing upward. Older larvae feed on the underside of broadleaf plants and devour the entire leaf. The larvae enlarge the bag as they grow. The bag may eventually grow to 30 to 50 mm long.

**c. Pupation.** Bagworms pupate inside their bag, which takes the place of a cocoon. The male moth emerges from his bag and flies to the female; he mates and dies in a short time. The male is black and has nearly clear wings.

**d. Female Bagworms.** Female bagworms never emerge from their bags or look like a moth. The adult female is legless, eyeless, and has no wings, legs, antennae, or functional mouthparts. She lays 500 to 1000 eggs within the bag. The eggs overwinter and hatch in early summer.

**e. Mobility.** Because bagworms can only move around as caterpillars, mobility is limited. Large populations may build up on one plant with lethal results for the plant.

**f. Natural Enemies.** A number of parasitic insects, such as the ichneumon wasp parasites, are important in controlling bagworm infestations.

## 6-8. SAWFLIES

Sawflies are non-stinging wasps which mostly feed on conifer needles. There are probably a hundred species of sawfly which feed on conifers in the larval stage. These insects resemble moth caterpillars, but may be separated by the number of prolegs on the abdomen.

**a. Description.** Caterpillars have two to five pairs of prolegs, while sawfly larvae have more than five pairs. The name "sawfly" comes from the saw-like structure at the tip of the female's abdomen. This "saw" is used to slit plant tissue so that eggs may be inserted. Sawflies are economic pests of pines and other conifers.

**b. Life Cycle.** Sawflies spend the winter in a prepupal stage, between larva and pupa, in a cocoon on the ground or under leaf litter.

- ◆ The insects complete pupation in the spring, and the adults emerge a few weeks later. Some prepupae wait two or three seasons before reaching adulthood. This "diapause" is probably a survival mechanism.
- ◆ Adults emerge from pupation, and the female cuts slits in plant tissue and lays over 100 eggs.
- ◆ The female may lay eggs without mating, but the unfertilized eggs produce only males. Fertilized eggs may produce either males or females.

**c. Generations.** Eggs hatch in about a month, and larvae feed in groups for about a month before dropping to the ground and spinning cocoons. Most sawfly species have one

generation per year in northern latitudes; some species may have up to five generations per year in the Gulf states.

## **d. Redheaded Pine Sawfly Larva.**

The redheaded pine sawfly larva is about one and one-fourth inch long, with a cream colored body, black spots, and a bright red head.

**e. Natural Enemies.** Rodents often control sawfly populations by feeding on pupae, and diseases can kill large numbers of larvae.

## 6-9. GYPSY MOTH

The gypsy moth is a familiar pest to residents of the northeastern United States. No other insect pest has caused so much damage or cost so much to control.

**a. Escape in Massachusetts.** The gypsy moth was introduced to Medford, Massachusetts by Mr. Trouvelot, an entomologist searching for a silk moth able to withstand growing conditions in America. The moth escaped from Mr. Trouvelot's home on Myrtle Street in 1869 or 1870, and became a problem to other residents of Myrtle Street within the next 12 years. The insects defoliated trees, dropped out of trees onto residents, and covered tree-trunks and houses. Streets and sidewalks were sometimes slippery with crushed caterpillars. The gypsy moth multiplied quickly in an environment with no natural enemies. Today the gypsy moth occupies most of the northeastern United States. The population has continued to move south and west.

**b. Host Trees.** Gypsy moth larvae feed on a number of host trees, including apple, basswood, oaks, willows, and some poplars. The insect avoids ash, black walnut, catalpa, red cedar, dogwood, holly, sycamore, and yellow poplar. Most hardwood trees will survive one or two seasons of defoliation before severe decline or death. Most conifers die after one complete defoliation. Oaks suffer more from the gypsy moth than other species.

**c. Larval Life.** Larvae hatch from early April to late May. The larvae may remain on the egg mass for a few days before climbing the tree to begin feeding. The larva spins a silk

thread and suspends itself from a leaf. The wind may blow the suspended larva to a new feeding area. This process is called ballooning. The larva feeds voraciously for about seven weeks, going through several molts. The full grown larva is two inches long with five pairs of blue spots and six pairs of red spots in a double row along the back.

**d. Pupation and Emergence.** The gypsy moth pupates in a brownish-black pupal case, and the adult moths emerge in mid-July.

**e. Mating.** Male adults are small and dark brown. The male gypsy moth is a good flyer, but the large white female is unable to fly. The female climbs to a high point and emits a sex attractant. The male moth can detect this volatile attractant from a distance of about a mile. After mating, the female deposits eggs on branches, buildings, fences, or other convenient places. The adults die soon after mating and egg deposition.

**f. Reproduction.** The female lays eggs in masses of 100 to 600, and covers the mass with tan or buff-colored hairs. The female often lays eggs on recreational vehicles, trucks, lumber, or other objects which are then moved across the country. Human activities account for the rapid spread of this rather immobile insect. The gypsy moth has one generation per year.

#### 6-10. CONTROL MEASURES: GENERAL CONSIDERATIONS FOR FOLIAGE FEEDERS

##### a. Nonchemical Control Methods.

- ◆ Burlap bands. Burlap bands can trap large caterpillars climbing on tree trunks. Removing and cleaning burlap maintains effectiveness.
- ◆ Sticky adhesive bands. Sticky adhesive bands trap caterpillars on tree trunks.
- ◆ Birds. Encourage birds by providing water, birdhouses, and other habitat.
- ◆ Destruction of egg masses and webbing. Destroy egg masses or tear down webbing. Burn or prune out webbing.

**b. Chemical control.** Follow these measures:

- ◆ Read and follow label directions.
- ◆ Spray entire tree when larvae are young and actively feeding.
- ◆ Use sticker/spreader in pesticide formulation so the insecticide sticks to foliage.
- ◆ Use *Bacillus thuringiensis*, neem oil, pyrethrin, viruses (for gypsy moth), or other low-toxicity insecticides when possible.

### Section III. JUICE FEEDERS

#### 6-11. INFORMATION

Insects with piercing, sucking mouthparts are able to attack plants by sucking out plant juices. The plants produce sugars and other nutrients necessary for insect life. Normally, a small infestation of juice-feeding insects is not life-threatening for a woody plant. Large infestations may deform the plant, introduce viral diseases, reduce growth, or actually kill the plant.

#### JUICE FEEDERS

- »» Aphids.
- »» Adelgids.
- »» Scales.

#### 6-12. APHIDS

These unusual insects are also called antcows or plant lice. Aphids are distributed worldwide, and few plants escape aphid feeding. Some aphid species are able to feed on a number of plant species, while others are very host specific.

**a. Identification.** Aphids are small, soft-bodied insects, no more than 1/16 to 1/8 inch long. Aphids are usually green, but may be black, brown, red, pink, or other colors. Aphids have long antennae and two tube-like projections (called cornicles) near the end of the abdomen. These insects change very little in appearance during their life cycle.

**b. Life Cycle.** Aphids have unusual life cycles, even for insects. A simple aphid life cycle starts with an overwintering egg which hatches in spring, producing a wingless "stem mother."

- ◆ The stem mother bears a large number of wingless, female young through a process called "parthenogenesis," which does not require mating.
- ◆ Eventually, perhaps after several generations, the stem mother bears winged males and females. The winged adults migrate, mate, and deposit eggs.
- ◆ This life cycle may be considerably more complicated in some aphid species, involving alternate host plants and sometimes different aphid forms.

**c. Damage.** Damage caused by aphid feeding includes discoloration, leaf curl, reduction of shoot growth, leaf fall, secondary invasion of pathogens, and plant death. Aphids typically cause leaf curl because the insect injects salivary material into the plant during feeding. The salivary material appears to be toxic to plant cells. Aphids usually feed on the underside of leaves. The aphid secretes a sticky substance called honeydew, which attracts ants. Sooty molds grow in the honeydew. Honeydew drips onto cars, sidewalks, picnic tables, etc.

### 6-13. ADELGIDS

Adelgids are similar to aphids, but lack cornicles. Adelgids also secrete waxy filaments around their bodies.

**a. Information.** These insects are extremely host-specific, and all attack some species of conifer. Some adelgids feed on a primary coniferous host, producing migrant

forms which move onto a secondary host. Adelgids have complicated life cycles with varying stages overwintering on the host tree.

**b. Damage.** Adelgids produce salivary secretions which cause reactions in host trees. The reactions range from gall formation and needle bending to twig dieback and tree death. The balsam wooly adelgid is a chronic tree killer, while many others only cause aesthetic problems. The hemlock wooly adelgid has devastated hemlock forests in the northeastern United States.

### 6-14. SCALES

Scales are immobile insects with piercing-sucking mouthparts. The insects lack legs, wings, antennae, and eyes. Scale insects look like bumps with a rounded, waxy shell. Scales may produce waxy wool like adelgids. They produce honeydew which promotes sooty mold growth and attracts ants.

**a. Damage.** Scales are found worldwide, infesting almost every species of plant. Plant damage occurs when the scales withdraw moisture from the plant, creating stress. Leaves yellow and may drop. Stress caused by scale feeding may result in plant death.

**b. Development.** Scales usually overwinter as adult females or nymphs. In spring, the female continues growing and deposits eggs under the waxy scale covering or produces live nymphs, depending on the species.

- ◆ First, instar nymphs (crawler stage) move or are blown to a point of attachment on leaves, fruit, or stems of plants.
- ◆ The crawlers insert mouthparts and begin feeding. They shed their old skins. Females lose their legs, antennae, and eyes and begin to form waxy shells.
- ◆ Adult males are often winged and usually live only a short time after mating.
- ◆ Scales may have hard or soft shells.
- ◆ Some females are slightly mobile, but most are completely immobile as adults.

## 6-15. CONTROL MEASURES GENERAL CONSIDERATIONS FOR JUICE SUCKING INSECTS

Natural predators, parasites, and disease may control the pest without intervention. Identify the pest before planning any control strategy.

### a. Nonchemical Controls.

- ◆ High pressure water spray or soapy water can control soft-bodied insects such as aphids.
- ◆ Carefully pruning trees and shrubs can eliminate immobile insects such as scales.
- ◆ Diatomaceous earth can control soft-bodied insects such as aphids.
- ◆ Dormant oil (or horticultural oil) can be used to control scale insects. The oil is sprayed on dormant hardwood trees to control the overwintering female scale. The oil coats the scale surface and forms an air-tight seal. The scale suffocates under the oil coating.
- ◆ Excess nitrogen can increase aphid and scale reproduction, so the minimum recommended amount of nitrogen fertilizer should be used on woody plants.
- ◆ Introduce insect predators such as ladybug beetles to control aphids.

### b. Chemical Controls.

- ◆ Read the label and use the pesticide as directed.
- ◆ Use low toxicity spray chemicals like soap and water, neem oil, pyrethrin, and horticultural oils.
- ◆ Spot treat when possible.

## Section IV. WOOD BORERS

### 6-16. INFORMATION

Wood borers tunnel just below the bark or within the wood, twigs, and stems of trees or woody ornamentals. These insects cause damage ranging from general decline to death from girdling. The insects can also introduce disease from a secondary insect, another disease, or drought damage. Insects feeding in the cambium layer just below the bark can quickly kill most woody plants.

#### WOOD BORERS

- »» European elm bark beetle.
- »» Twig girdler.
- »» Bark beetle.
- »» Flathead beetle.
- »» Longhorned beetle.

### 6-17. EUROPEAN ELM BARK BEETLE

The European elm bark beetle lives wherever elm trees are found. It is native to Europe, as the name implies. It was first discovered in the United States in 1904, near Boston, Massachusetts. The European elm bark beetle has spread to most of the states east of the Rocky Mountains and to Utah, Nevada, Oregon, California, and Canada. This beetle and the native elm bark beetle were of little concern until Dutch elm disease became established in the United States. The elm bark beetles are the vector for introducing Dutch elm disease to healthy elm trees.

**a. Life Cycle.** The larva burrows into elm bark and overwinters. Larvae continue to develop in spring and then pupate. Adults emerge in mid-May.

**b. Disease Transmission.** Adults feed on young bark, mainly the bark in the crotch of elm twigs. The female lays eggs in galleries of dead and dying elm bark. She bores into an

unhealthy elm tree and builds an egg-laying gallery parallel to the grain of the wood. After hatching, larvae bore tunnels radiating away from the egg-laying gallery. Adults pick up spores of Dutch elm disease from a diseased tree, mechanically transmitting the disease.

#### **6-18. TWIG GIRDLE**

**a. Information.** This insect is unique in appearance and habits. The twig girdler causes little feeding damage, but may damage trees as part of an unusual reproductive strategy.

**b. Damage.** Adult female twig girdlers deposit eggs on a twig, then girdle the twig. The twig breaks in the wind and falls. Larvae hatch and bore into the twig on the ground.

#### **6-19. BARK BEETLES**

Bark beetles are devastating pests of coniferous trees, especially older, mature, pines. There are over 600 species commonly called bark beetles. The beetles are attracted to trees weakened by lightning strike, excavation, backfilling over the root zone, mechanical damage, soil compaction, smog, or overmaturity.

**a. Development/Damage.** Beetles overwinter beneath the bark of the host tree as larvae, pupae, or adults, depending on the species. Adults emerge in spring and fly in search of new host trees. Some species are attracted to the odor of injured or weakened trees. Adult beetles bore through the bark, mate, and excavate egg galleries in the spongy inner bark. The first beetles to enter a tree emit a powerful pheromone to attract other beetles. The beetles may kill a healthy tree by numbers alone. Legless grubs hatch in four to nine days, feed in the inner bark, bore to outer bark, pupate, and emerge. Some bark beetles move from a population center in a damaged tree to healthy trees nearby.

**b. Adult Bark Beetles.** Adult bark beetles are small, stout, reddish-brown, or dark colored beetles. Bark beetles may have from one to six generations per year, depending on the species.

#### **6-20. FLATHEAD BEETLES**

Flathead beetles are important pests of shade trees in the United States. There are several species of this common type of insect. Flathead beetles usually attack trees stressed by overpruning, drought, replanting, or other environmental conditions.

**a. Development.** The larvae, called grubs or borers, overwinter deep in the wood of the tree. Larvae are medium to large, yellowish-white, legless grubs with a pronounced enlargement of the body just behind the head. In spring, the grubs pupate, and the adults emerge in spring through summer. Adults are metallic, beautifully colored, boat-shaped beetles. The flatheaded beetles prefer sunny locations, and more insects are always found on the sunny side of the tree.

**b. Damage.** Adults fly to an unhealthy tree or an area of damaged bark and lay eggs in cracks of the bark. Larvae emerge, bore into the tree, and feed in the phloem (inner bark) tissue. During fall, the grubs bore deep into the tree trunk to overwinter in the heartwood.

#### **6-21. LONGHORNED BEETLES**

The larvae of these large beetles are called roundheaded borers. Adults are long with unusually long, five-segmented antennae. Adults feed on leaves and pollen, and larvae tunnel into the heartwood of trees and shrubs. Examples include the locust borer, red-headed ash borer, pine sawyers, roundheaded apple tree borer, and twig pruners.

**a. Development.** The life cycle of longhorned borers is quite long. Some species live two to four years. Pupation occurs in galleries excavated by larvae during the spring of the last year of larval life. Adults emerge in early summer and immediately begin to lay eggs in tree trunk cavities, close to the ground. The larvae hatch and bore into the tree to begin feeding.

**b. Damage.** Larvae damage trees by feeding in the cambium region of the tree trunk, which may girdle the tree; and by feeding in the

heartwood of the tree, which mechanically weakens the tree trunk so it may break in the wind.

#### 6-22. CONTROL MEASURES AND GENERAL CONSIDERATIONS FOR WOOD BORING INSECTS

Control is difficult because larvae are below the bark, and adults are not exposed for long periods of time. Predators help to some extent.

**a. Plant Health Care.** Plant health care is the key to protection from wood borers. This involves fertilization, watering during drought stress periods, protection from mechanical damage, proper planting, use of resistant species, and removal of overmature trees.

**b. Salvage Cutting.** Salvage cutting is often the only way to arrest a rapidly spreading infestation of bark beetles. Infested trees are harvested before the beetles can complete their life cycle and move to another tree. Pruning and destroying infested branches can control an infestation of wood borers.

**c. Contact Insecticides.** Contact insecticides may be applied to tree trunks and large branches to prevent infestation and kill hatching larvae.

**d. Systemic Insecticides.** Systemic insecticides enter the vascular phloem tissue of the tree. Borers feeding in the phloem tissue absorb a lethal dose of insecticide.

**e. Fumigants.** Fumigants may be injected into borer tunnels to control larvae.

### Section V. GENERAL CONTROL TECHNIQUES

#### 6-23. PROPERLY LABELED INSECTICIDES

Controlling insect pests of landscape plants is only one part of a total plant health care program. Healthy plants are usually able to

resist or survive insect feeding. If management measures are necessary, emphasize cultural controls, which are safer and usually more permanent than chemicals. Cultural controls include:

- ◆ Resistant trees/shrubs.
- ◆ Pruning.
- ◆ Fertilization (avoid excessive nitrogen).
- ◆ Watering.
- ◆ Correct planting techniques.
- ◆ Removal/salvage of overmature or damaged plants.

#### 6-24. SEVERE INSECT INFESTATIONS

Properly labelled insecticides may be necessary to control severe insect infestations. If insecticides are used:

- ◆ Follow all label instructions.
- ◆ Avoid drift and run-off.
- ◆ Emphasize low-toxicity insecticides such as neem oil, *Bacillus thuringiensis*, pyrethrins, soapy water, and dormant oils.
- ◆ Keep people and domestic animals out of the area.

## EXERCISES, LESSON 6

**REQUIREMENT.** The following exercises are to be answered by selecting the correct letter, completing the incomplete statement, or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

1. \_\_\_\_\_ adults are reddish-brown with two whitish stripes running obliquely across each forewing. This insect is considered the most widespread defoliator in the Eastern United States.
2. This male emerges from his bag, flies to the female, mates and dies in a short time. He is black and has nearly clear wings. Feeding on more than 120 trees and shrubs, this insect is named the \_\_\_\_\_.
3. Small, soft-bodied insects, no more than 1/16 to 1/8 inch long, \_\_\_\_\_ have long antennae and two tube-like projections near the end of the abdomen. These insects typically cause leaf curl because they inject salivary material into the plant during feeding.
4. Older, mature pine trees, especially those weakened by lightning strike, excavation, soil compaction, or smog attract \_\_\_\_\_ beetles. These insects bore through the bark, mate, and excavate egg galleries in the spongy inner bark.
5. List three cultural controls in controlling insect damage to trees and ornamental plants.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
6. \_\_\_\_\_ are immobile insects with piercing-sucking mouthparts. They look like bumps with a rounded, waxy shell and produce honeydew which promotes sooty mold growth and attracts ants.
7. Adult \_\_\_\_\_ beetles are metallic, beautifully colored, and boat-shaped. They prefer sunny locations and are always found on the sunny side of a tree.
8. Pruning and destroying infested branches are methods of controlling an infestation of \_\_\_\_\_.
9. The \_\_\_\_\_ feeds on a number of trees--oaks, willows, some poplars, and apple--but avoids other trees including ash, black walnut, dogwood, and holly.
10. The larva of the \_\_\_\_\_ caterpillar are two inches long with white keyhole shaped spots down the middle of the back and blue lines along the sides.

### END OF LESSON EXERCISES



## LESSON ASSIGNMENT

<b>LESSON 7</b>	-- Aquatic Weeds.
<b>LESSON ASSIGNMENT</b>	-- Paragraphs 7-1 through 7-47.
<b>TERMINAL LEARNING OBJECTIVE</b>	-- Information gained in this lesson should enable you to manage aquatic plants using integrated pest management principles and techniques.
<b>SPECIFIC LESSON OBJECTIVES</b>	-- After completing this lesson, you should be able to:  7-1. Identify the damage caused by aquatic plants.  7-2. Identify the four growth habitats of aquatic plants and match each growth habit with a common aquatic weed.  7-3. Identify nonchemical controls of aquatic weeds and the advantages and disadvantages of each method.  7-4. Identify the factors to be considered in designing an aquatic plant management program.  7-5. Identify the environmental factors which affect aquatic herbicide applications.  7-6. Identify the environmental hazards associated with the use of aquatic herbicides.  7-7. Calculate the total herbicide application for a given body of water.
<b>SUGGESTION</b>	-- After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 7

### AQUATIC WEEDS

#### Section I. INTRODUCTION

##### 7-1. GENERAL INFORMATION

Aquatic vegetation management is extremely complex, and is further complicated by the risk of harming human health or the environment. Aquatic weeds can completely occupy bodies of fresh water, destroying natural ecosystems and reducing human use of the water. During this block of instruction, we will discuss some of the more common and troublesome aquatic weeds, and consider the basic principles of aquatic plant management. Both chemical and non-chemical management techniques will be considered.

#### AQUATIC WEED DAMAGE

Aquatic weeds can reduce human use of fresh water and destroy natural ecosystems.

##### 7-2. HISTORY OF AQUATIC WEED CONTROL

The history of aquatic plant management in the United States is a history of non-indigenous, invasive plants. Although early explorers of the Southeast reported some waterways clogged with native aquatic plants, these species were generally held in check by indigenous insects, diseases, and vertebrates which used the plants for food and shelter.

##### 7-3. WATER HYACINTH

In 1884, water hyacinth was introduced to Florida from Louisiana. The plant was purchased by a Florida resident during the Louisiana EXPO and planted in an aquatic garden on the banks of the St. Johns river.

Heavy rains washed the plant into the St. John's river. The water hyacinth has expanded its range north, east, and west since then.

##### 7-4. ALLIGATORWEED

In 1885, alligatorweed was accidentally introduced to Florida. Alligatorweed was introduced from South America in ship ballast. A ship anchored in the mouth of the Orinoco river apparently took on ballast water containing seeds or plant parts of the Alligatorweed. The ship later discharged its ballast water into the St. John's river.

##### 7-5. RIVER AND HARBOR ACT

By 1899, aquatic plants filled the St. John's river basin in Florida, blocking steamboat traffic. Congress enacted the River and Harbor Act, authorizing removal and containment of water hyacinths in Florida and Louisiana. The US Army Corps of Engineers was directed to take all necessary action to clear waterways of the noxious weeds.

##### 7-6. CHEMICAL CONTROL

Congress acted again in 1902 to authorize control of water hyacinths by any mechanical, chemical, or other means. The materials tested include:

- ◆ Muriatic acid.
- ◆ Sulfuric acid.
- ◆ Carbolic acid.
- ◆ Kerosene.
- ◆ Steam.
- ◆ Sodium arsenite.
- ◆ Copper sulfate.

##### 7-7. CHEMICALS PROHIBITED

Although several of these chemicals were effective against water hyacinths, and copper sulfate is still widely used to control algae, most of the chemicals are highly toxic. In 1905, Congress prohibited the use of chemicals injurious to cattle or man (in that order) to control aquatic plants. This left would-be aquatic plant managers without a chemical arsenal, since all of the materials used were toxic to cattle and man.

## 7-8. MECHANICAL CONTROL

Aquatic plant management remained a strictly mechanical endeavor from 1900 to 1950. Mechanical methods were unable to control either water hyacinths or alligator weeds.

## 7-9. EURASIAN WATERMILFOIL

In 1942, Eurasian watermilfoil was identified in the District of Columbia. This non-indigenous plant has since spread throughout large portions of the Northeast.

## 7-10. SELECTIVE HERBICIDE

The selective herbicide 2,4-D was discovered during World War II. This herbicide kills dicotyledons or broadleaf plants. In 1947, researchers used 2,4-D successfully control water hyacinths. The Army Corps of Engineers soon began to use 2,4-D against other aquatic weeds. Chemists developed other organic herbicides capable of controlling aquatic vegetation.

## 7-11. HYDRILLA

During 1959, the noxious weed hydrilla was discovered in Florida. Aquarium owners apparently introduced this plant to Florida by dumping aquariums into lakes and streams.

- ♦ The hydrilla plant is native to Southeast Asia. The plant is diecious (having male and female plants), and only female plants were introduced.
- ♦ The plant does not produce seeds in the United States, but spreads by vegetative means.

## 7-12. BIOLOGICAL CONTROL

Researchers initiated a new age of aquatic plant management during the period 1964 to 1971, by releasing biological control agents for alligatorweeds. During 1972 to 1977, officials released water hyacinth weevils and a water hyacinth moth. These insects have been

extremely effective at controlling their aquatic hosts, and researchers continue to search for more effective biological control agents.

## 7-13. CURRENT ISSUES

The aquatic plant wars continue unabated. Although biological control agents have reduced the population of water hyacinths and alligatorweeds, hydrilla has covered most of the Southern United States in 30 years.

- ♦ Careless or misguided individuals continue to introduce invasive plants to the United States.
- ♦ Officials are now trying to deal with melaluca trees, a wetland tree species which has colonized huge areas of the Florida Everglades.
- ♦ Purple loosestrife is another wetland species which has rapidly spread throughout the Northeast.

### AQUATIC PLANT CURRENT ISSUES

#### Controlled:

- ♦ Biological Control -- reduction in water hyacinths and alligatorweed.
- ♦ Hydrilla -- covered most of the Southern states in the last 30 years.

#### Trying to control:

- ♦ Melaluca trees -- species of wetland tree growing in Florida Everglades.
- ♦ Purple loosestrife -- species of wetland plants flourishing in the Northeastern United States.

## Section II. BENEFITS OF NATIVE AQUATIC PLANTS

### 7-14. BENEFITS OF NATIVE AQUATIC PLANTS

Aquatic plant managers must remember that native plants are almost always beneficial.

### 7-15. FOOD CHAIN

Plants form the basis of the aquatic food chain. Algae and aquatic macrophytes provide food for small animals, which become the food for successively larger animals.

### 7-16. WILDLIFE HABITAT

Plants provide shelter and breeding habitat for animals, including fish, waterfowl, and aquatic mammals.

### 7-17. STREAM STABILIZATION

Plants stabilize streambanks and riverbottoms, decreasing erosion due to heavy rains or boat wakes.

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## Section III. GROWTH AND NEGATIVE IMPACT

### 7-18. REASONS FOR WEEDY GROWTH

Aquatic weed problems are closely linked to certain environmental conditions.

- ◆ Water condition--clear, shallow water, which allows penetration of sunlight to the bottom of the water. Aquatic plants thrive under these high light conditions.
- ◆ Adequate nutrients--especially nitrogen and phosphorus. These nutrients are washed into surface water in storm drainage, which transports fertilizers, agricultural waste, and sewage.

- Aquatic plants respond rapidly to nutrient-rich waters.
- Native aquatic plants sometimes grow very quickly and invade new territory when waters are enriched with fertilizer nutrients.

- ◆ Exotic species--introduction of exotic species. Introduced species grow quickly in a habitat with no natural enemies.

### 7-19. NEGATIVE IMPACTS OF AQUATIC WEEDS

Aquatic weeds cause problems because of their unrestricted growth. In effect, the plants are too successful for our own good, or the good of other species sharing the aquatic habitat. From our standpoint, aquatic plants:

- ◆ Restrict recreational uses of fresh water such as fishing, boating, swimming, and water skiing.
- ◆ Restrict industrial or household use of water by invading reservoirs and blocking water flow. Algae may grow in reservoirs and impart a strong, disagreeable flavor to drinking water.
- ◆ Clog irrigation canals and livestock ponds.
- ◆ Clog drainage canals, blocking water flow and causing flooding during rainstorms.
- ◆ Create a habitat for disease vectors such as mosquitoes.
- ◆ Completely alter biological systems, often at the expense of native species.
- ◆ Non-native aquatic plants may affect protected species by degrading the critical habitat of those organisms.

### **AQUATIC WEEDS -- THE NEGATIVES FOR PEOPLE**

- ◆ Restrict recreational uses of fresh water.
- ◆ Restrict industrial or household use of water.
- ◆ Clog irrigation canals.
- ◆ Clog drainage canals.
- ◆ Create habitats for disease vectors.
- ◆ Completely alter biological systems.

## **Section IV. TYPES AND GROWTH HABITATS**

### **7-20. BOTANICAL GROUPS**

Aquatic plants may belong to several botanical groups. Most aquatic weeds are vascular plants. The algae may also be a significant problem in warm, shallow water. Aquatic plants also occupy different parts of the water. Major aquatic plant groups are algae, ferns, and flowering plants.

#### **7-21. ALGAE**

Algae are single-celled or multi-celled plants which lack true supporting or conducting tissues. The algae must live in association with water, so there are no true terrestrial algae. The algae are further divided according to life cycles and pigmentation. The bluegreen and green algae are the most important groups in freshwater.

**a. Planktonic Algae.** These algae are single-celled organisms (sometimes small

colonies of cells) which float or live suspended in the water column. Planktonic algae seldom present a pest management problem.

**b. Filamentous Algae.** Filamentous algae are multi-cellular plants with the cells attached end to end to form long threads. The interlocking threads form floating or sunken mats of tissue. The green algae *Spirogyra* spp. and the blue-green algae *Lyngbya* spp. are examples of troublesome filamentous algae.

**c. Macrophytic Algae.** These plants are large, multi-cellular, branching algae. Two important macrophytic algae are muskgrass (*Chara* spp.) and stonewort (*Nitella* spp.).

### **7-22. FERNS**

Ferns belong to the group of plants which possess true supporting and conducting tissues. Ferns do not produce flowers or seeds, but reproduce by the formation of *spores*. The spores are formed in spore cases on the lower side of the leaves.

- ◆ There are only two aquatic ferns in the United States. These are the water fern (*Salvinia minima*) and the mosquito fern (*Azolla caroliniana*).
- ◆ Both of these ferns are small floating plants with unattached roots hanging freely in the water.

### **7-23. FLOWERING PLANTS**

Flowering plants, like ferns, have true supporting and conducting tissues. Many of these plants are able to live in terrestrial environments. Flowering plants are separated from the ferns because they reproduce by producing flowers and seeds rather than spores.

- ◆ Most aquatic weeds are flowering plants.
- ◆ Aquatic plants may be monocotyledons (with parallel veins and flower parts in groups of three) or dicotyledons (with netlike veins and flower parts in groups of four and five).

- Aquatic monocots include torpedograss, maidencane, giant reed, Southern bulrush and soft rush.
- Aquatic dicots include hydrilla, water hyacinth, water lettuce, and Eurasian watermilfoil.

## Section V. GROUPING OF AQUATIC PLANTS

### 7-24. PLANT GROUPING

Botanists further group aquatic plants according to *where* they grow in the water. These groups are as follows:

#### 7-25. SUBMERSED PLANTS

Submersed plants grow completely beneath the water surface and depend on water to support the plant body. Hydrilla, Eurasian watermilfoil, American eelgrass, and coontail are examples of submersed plants.

#### 7-26. EMERSED PLANTS

Emersed plants are rooted in the bottom and extend above the water surface. These plants usually grow in shallow water and are self-supporting. Alligatorweed, cattail, bulrush, and maidencane are examples of emersed plants.

#### 7-27. FLOATING PLANTS

Floating plants are not attached to the bottom and float on the water surface. Water fern, water hyacinth, American frogbit, and waterlettuce are examples of floating plants.

#### 7-28. FLOATING LEAF PLANTS

Floating leaf plants are attached to the bottom and have leaves that float on the surface. These plants may or may not be self-supporting. Some floating leaf plants can live in an emersed

growth habit. Waterlilies, American lotus, and watershield are examples of floating leaf plants.

## Section VI. NON-CHEMICAL CONTROL

### 7-29. NON-CHEMICAL CONTROLS

It is often possible to control aquatic weeds without the use of herbicides, or to use herbicides in conjunction with other, non-chemical methods. We will consider several vegetation control techniques.

### 7-30. BIOLOGICAL CONTROL

Biological control is the use of fish, insects, pathogens, or other organisms for aquatic plant control. Although any number of organisms feed on aquatic plants, many (such as water buffalo and hippopotamus) are not always compatible with human use of the water. The most commonly used biological control agents have been fish and insects. Biological control can be extremely effective, but great care is needed when selecting and establishing a control agent.

a. **Fish.** Two species of fish have been used to control aquatic plants in the United States. These species are the grass carp and the tilapia.

- ◆ Grass carp. The Chinese grass carp feed on submersed plants, or any plant material they can reach. These fish will graze grass and weeds from the banks of a pond when the aquatic weeds are depleted. Some lake managers feed green hay or grass clippings to the carp.

- Grass carp are most useful when stocked at levels of 20 to 25 fish per acre.
- Usually, it is necessary to obtain a permit from the Fish and Wildlife Service before stocking grass carp.

- The grass carp used in the United States are triploid fish with three sets of chromosomes and are sterile.
- It's necessary to use sterile grass carp, because a fertile population of these fish could devastate native fresh-water plants.
- ◆ Tilapia. Tilapia feed on filamentous algae and other soft vegetation. These fish originated in the Nile River.
  - We stock tilapia at the rate of 300 fish per acre.
  - Tilapia cannot live in water below 65° F, so winter kill is a risk in temperate areas.
  - Unlike grass carp, these fish are considered edible and are served in restaurants in Florida.

**b. Insects.** Several species of insects feed on aquatic plants. Insects which control important aquatic weed species include:

- ◆ Alligatorweed flea beetles.
- ◆ Waterhyacinth weevils.
- ◆ Waterlettuce weevils.
- ◆ Hydrilla tuber weevils.
- ◆ Hydrilla leaf-mining flies.

## 7-31. MECHANICAL CONTROL

Mechanical removal is an important technique in controlling aquatic weeds. In certain circumstances, this method has several advantages over the use of herbicides or other control methods.

**a. Advantages of Mechanical Control.** Included are the following:

- ◆ Control is immediate, and there is no time lost while plants sink and decay.
- ◆ Water may be used immediately. There are none of the water use restrictions associated with certain herbicides.

- ◆ Nutrients found in plants are removed from the water, so algal blooms aren't likely following treatment.

**b. Disadvantages of Mechanical Control.** Included are the following:

- ◆ Machines designed to remove aquatic weeds are costly. Maintenance and repair of this equipment is expensive.
- ◆ It's often impractical to mechanically remove aquatic plants due to limits such as water depth or obstructions.
- ◆ Mechanical removal is much slower than other methods of aquatic weed control.
- ◆ It's difficult to dispose of harvested plants.
- ◆ Machinery operation may increase turbidity.
- ◆ The machines remove wildlife and desirable vegetation along with weeds.
- ◆ Plant fragments drift to infest new areas during harvest.

**c. Water Level Manipulation-- Drawdown.** Raising water levels to drown aquatic plants or lowering water levels to expose the plants to freezing, drying or heat, are sometimes effective control techniques. Usually, lowering water levels (drawdown) to dry or freeze aquatic plants is more effective than raising water levels.

- ◆ This weed control method is limited to reservoirs with water control structures.
- ◆ Drawdown is very effective against certain submersed species such as Brazilian elodea, but much less effective against similar species like hydrilla.
- ◆ Hydrilla can survive several consecutive drawdowns.
- ◆ Emergent plants easily tolerate drawdowns.

NON-CHEMICAL CONTROLS		
	BIOLOGICAL CONTROL	MECHANICAL CONTROL
<b>DEFINITION</b>	<ul style="list-style-type: none"> <li>♦ The use of fish, insects, pathogens, or other organisms for aquatic plant control.</li> </ul>	<ul style="list-style-type: none"> <li>♦ The physical removal of aquatic weeds by hand, tools, or machines.</li> </ul>
<b>ADVANTAGES</b>	<ul style="list-style-type: none"> <li>♦ Long-term control.</li> <li>♦ No restrictions on water use.</li> <li>♦ Often does not require reapplication/release.</li> </ul>	<ul style="list-style-type: none"> <li>♦ Control is immediate.</li> <li>♦ Use water immediately.</li> <li>♦ No algae after treatment.</li> </ul>
<b>DISADVANTAGES</b>	<ul style="list-style-type: none"> <li>♦ Slow.</li> <li>♦ Expensive initially (research/propagation of control agent)</li> <li>♦ Potential for escape to desirable plants.</li> </ul>	<ul style="list-style-type: none"> <li>♦ Removal machines expensive.</li> <li>♦ Often impractical.</li> <li>♦ Removal slow.</li> <li>♦ Problem disposing of removed plants.</li> <li>♦ Increase in turbidity.</li> <li>♦ Machines also remove wildlife and desirable vegetation.</li> <li>♦ Plant fragments drift and infect other areas.</li> </ul>

Table 7-1. Non-chemical control of aquatic weeds.

- ♦ Drawdown is a very inexpensive weed control technique, but sufficient water must be available to refill the reservoir.

**d. Light Penetration.** All plants require light to grow. Submersed aquatic plants must absorb sunlight which has been filtered through water.

- ♦ By reducing the amount of light which penetrates into water, we can suppress plant growth.
- ♦ Aquatic dyes. Specially designed aquatic dyes block out the light spectrum needed for plant growth.
  - These dyes are non-toxic to wildlife, human beings and fish in the lake.

- Aquatic dyes can only work if the lake or pond has little water flow, and if the water depth is more than three feet.

- ♦ Bottom covers. Bottom covers may be used in small ponds to shade out rooted aquatic plants.

## Section VII. CHEMICAL CONTROL

### 7-32. GENERAL INFORMATION

As of this writing, aquatic pest managers still use herbicides more than any other technique of weed control. Herbicides are faster, more convenient, and often less expensive than other available methods. Managers will certainly

turn more and more to biological control in the future, either alone or in an integrated program. The Army Corps of Engineers is presently collecting information about all the effective control methods for various aquatic plants, and making that information available in an "expert" system for aquatic plant managers.

### 7-33. AQUATIC HERBICIDES

Compared to farmers or golf course superintendents, aquatic vegetation managers have an easy time choosing herbicides.

- ◆ The EPA has registered only seven herbicides for aquatic use.
- ◆ The reason for the low numbers of aquatic herbicides is the aquatic environment, which limits the number of compounds which will be effective and still meet standards for human and environmental safety.
- ◆ The seven aquatic herbicides are as follows:
  - Copper--a contact herbicide affecting plant photosynthesis.
  - Diquat--a contact herbicide affecting plant photosynthesis.
  - Endothal--a contact herbicide affecting plant respiration.
  - 2,4-D--a systemic herbicide affecting plant tissue development.
  - Dichobeni--a systemic herbicide affecting plant cell division.
  - Fluridone--a systemic herbicide affecting plant photosynthesis.
  - Glyphosate--a systemic herbicide affecting nitrogen metabolism and enzyme activity.

## Section VIII. HERBICIDE APPLICATION EQUIPMENT

### 7-34. TYPES OF EQUIPMENT

Most aquatic weed managers apply herbicides using one of four basic types of equipment.

#### APPLICATION EQUIPMENT

- ◆ Handgun sprayer.
- ◆ Subsurface injection.
- ◆ Bottom placement.
- ◆ Granular spreader.

### 7-35. HANDGUN SPRAYER

Applicators use the handgun sprayer to treat surface, emersed, and ditch bank species. The handgun sprayer consists of a tank with an agitator, a pump, a chemical resistant pressure hose, and the handgun. Handguns are fitted with high flow rate nozzles (three to six gallons per minute). The applicator can thoroughly wet vegetation with minimum drift.

### 7-36. SUBSURFACE INJECTION

Applicators use subsurface injection just below the water to treat submersed weeds. The injection equipment consists of a tank with an agitator, a pump, a bow or stern mounted boom, and short hoses ending in nozzles. The applicator sets the nozzles to discharge herbicide just below the water surface.

### 7-37. BOTTOM PLACEMENT

The applicator may wish to place herbicide near the bottom of the water. Bottom application is accomplished with long, trailing hoses attached to a bow-mounted boom. The equipment consists of a tank with an agitator, a pump, a boom, and long hoses with weighted

nozzles. The applicator must remove any clamps or protrusions from the nozzles, since these might catch and hold plants.

#### 7-38. GRANULAR SPREADERS

The applicator may want to apply a granular herbicide, in which case he may use a simple granular spreader. The applicator mounts granular spreaders on the bow of the boat. The equipment is a centrifugal or blower-type spreader which uses a rotating disk or air pressure, and a venturi discharge nozzle to propel the granules.

### Section IX. ENVIRONMENTAL FACTORS AND HERBICIDE

#### 7-39. ENVIRONMENTAL FACTORS AFFECTING HERBICIDE APPLICATIONS

Because the aquatic environment is so complex, the applicator must be aware of the forces which may alter the effect of herbicide applications

#### 7-40. WEATHER CONDITIONS

The applicator must be aware of three weather factors.

- ◆ Rainfall--A sudden rainstorm may wash herbicide off treated plants before the chemical is absorbed. Systemic herbicides such as glyphosate move into the plant system slowly. Contact herbicides move into the plant very quickly and are less vulnerable to rain.
- ◆ Wind--Foliar herbicide applications may be affected by wind which results in poor coverage. Drift is a constant hazard during windy conditions. Wind can also cause water movement which carries herbicide away from submersed weeds. In summary, avoid windy conditions during herbicide applications.

- ◆ Temperature--Plants must be actively growing for proper herbicide activity. Cold temperatures may affect herbicide activity by slowing plant growth. Foliar applied herbicides may volatilize before absorption during very high temperatures.

#### 7-41. WATER MOVEMENT

Herbicides used for control of submersed aquatic plants must be in contact with plant tissue long enough for absorption. Rapidly flowing water carries herbicides away from the target plants before absorption can occur. The applicator must take precautions even in slowly moving water. Methods to control aquatic weeds in slowly moving water include:

- ◆ Invert emulsions or polymer formulas and deep-water injection to help the herbicide sink and adhere to submersed plants.
- ◆ Special formulations such as slow release pellets which sink to the bottom and release small amounts of herbicide over a long period of time.
- ◆ Rapidly absorbed herbicides such as diquat.
- ◆ Sequential applications or injection equipment to increase contact time between herbicide and plant tissue.

#### 7-42. WATER CHEMISTRY

There are three parameters of water chemistry which may affect aquatic herbicides. The three parameters are:

- ◆ pH--pH is a measure of the acidity or alkalinity of the water. The pH scale ranges from 0 to 14, with 7 indicating neutral. pH values above 7 are alkaline, and values below 7 are acidic. The applicator must be aware that pH values may affect herbicide treatment. For example, 2,4-D amine herbicide is more active at pH values of less than 6. The

applicator cannot change aquatic pH values, but lower rates may be used if the herbicide is more active at low pH values.

- ◆ Turbidity--Turbidity is a measure of particles suspended in the water. Water-borne particles may be inorganic (clay or minerals), biotic (plankton), or organic.
  - Clay and organic particles may bind to herbicides such as diquat or glyphosate and inactivate the herbicide.
  - The applicator must be careful to use clean diluent water in the herbicide tank, and avoid stirring up the sediment in shallow waters.
- ◆ Water hardness--Water hardness is caused by dissolved metals such as calcium, magnesium, iron and strontium.
  - Water hardness is measured in ppm of calcium carbonate.
  - Hardness is usually in the range of 10 to 100, but values of 150 to 300 are common in some regions.
  - Hard water may inactivate or precipitate the herbicides copper sulfate and glyphosate. It's important to use soft water when mixing glyphosate or copper.
  - If the applicator must mix these herbicides with hard water, he should minimize the time the herbicides remain mixed in the tank.

#### 7-43. HERBICIDE FATE IN THE ENVIRONMENT

The public is understandably concerned about the fate of aquatic herbicides. Since fresh water is essential to so many human activities, the EPA will not allow the use of persistent

herbicides for aquatic purposes. The fate of aquatic herbicides in the aquatic environment is as follows:

- ◆ 2, 4-D--broken down by microbial degradation, and photodecomposition; half-life 7 to 48 days.
- ◆ Diquat--taken up by plants and adsorbed by sediments; half-life one to seven days.
- ◆ Copper--forms insoluble compounds with other elements or binds to charged particles; copper does not break down, but is inactivated.
- ◆ Endothall--broken down by microbial activity; half-life four to seven days.
- ◆ Fluridone--broken down by photodegradation and microbial degradation; half life 20 days.
- ◆ Glyphosate--degraded by microbial activity; half-life 14 days.
- ◆ Dichobenil--broken down by microbial activity, adsorption to charged particles and volatilization; half-life 60 to 90 days. Dichobenil is applied as a granule and has low water solubility, so it occurs in low concentrations.

### Section X. PROGRAM DESIGN FOR AQUATIC PLANT CONTROL

#### 7-44. THE GOAL

The aquatic plant manager must keep several factors in mind when designing a weed control program. The ideal is to create an effective, but safe and environmentally sound program.

## 7-45. FACTORS TO CONSIDER

Factors to consider include:

- ◆ Type of plant--Control strategies effective on one species may be ineffective even on very similar species. Furthermore, the plant growth habitat--floating, submersed, emersed, or floating-leaf--may determine possible control strategies.
- ◆ Herbicide restrictions--Use of the water-aquatic herbicides may have restrictions associated with water use following application.
  - Common water use restrictions include swimming, eating fish, watering livestock, and irrigating.
- ◆ Physical constraints--Aquatic plant managers must use specialized equipment such as air boats and boat-mounted application equipment. This equipment is not always readily available.
  - The manager must gain access to aquatic weeds, sometimes in swampy locations far away from roads or boat ramps.
- ◆ Possible impact--Possible impact on fisheries and wildlife, including endangered species, must be considered.
  - It's possible to kill fish and other aquatic organisms in at least two ways during a plant control operation.
  - First, the applicator may overtreat with herbicide, causing toxicity to fish.
  - Second, the applicator may treat too large a percentage of the water with herbicide.
  - As plants die, they are broken down by microorganisms.

- The microbes use dissolved oxygen from the water and deplete oxygen reserves.
  - If the dissolved oxygen percentage falls too much, a fish kill may result.
  - The applicator must strictly follow label guidelines regarding the percentage of a lake or pond which may be treated at one time.
- ◆ Effects on native aquatic plants--Herbicide treatments must be directed away from native plants whenever possible, or the application may be timed to avoid damage to native plants.

### PROGRAM DESIGN FACTORS

- ◆ Type of plant.
  - Control strategies.
  - Growth habitat.
- ◆ Herbicide restrictions.
  - Swimming.
  - Eating fish.
  - Watering livestock.
  - Irrigating.
- ◆ Physical constraints.
  - Equipment availability.
  - Access to area.
- ◆ Possible impact.
  - Fish kill.
  - Plant expiration.
  - Oxygen depletion in water.
- ◆ Effects on native aquatic plants.
  - Possible damage.

## Section XI. HERBICIDE CALCULATIONS

### 7-46. HERBICIDE CALCULATIONS

a. **Aquatic Herbicide Application Rates.** Aquatic herbicide application rates are based on acre-feet or parts per million. Acre feet are calculated using the formula:

$$\text{Acre Feet} = \frac{\text{Surface area (square feet)}}{43,560 \text{ (square feet / acre)}} \times \text{Average depth}$$

Example: The acre feet of a roughly circular pond with a diameter of 150 feet and average depth of 5 feet is:

$$\text{Acre feet} = \frac{3.14 \times (75\text{ft})^2}{43,560\text{ft}^2 / \text{acre}} \times 5 \text{ ft} = 2.03 \text{ acre feet}$$

b. **Average Depth.** Average depth is determined by taking a series of soundings in two directions, summing the results, and dividing by the number of soundings.

**Remember:** The first sounding in each direction has a zero value.

c. **Parts Per Million.** Parts per million may be determined using the acre foot value. Remember each acre foot equals 43,560 cubic feet of water. Each cubic foot of water equals 28.32 liters. Since parts per million equals grams per liter of water, the applicator can determine parts per million by using the formula:

$$\text{PPM} = \frac{\text{Pounds of herbicide} \times 453.6 \text{ grams / pound}}{\text{Acre feet} \times 43,560 \times 28.32 \text{ liter / cubic foot}}$$

Example: Two gallons of aquathol are applied to a rectangular catfish pond having sides measuring 150 feet by 100 feet with an average depth of 4 feet. What is the concentration of active ingredient in pond?

**NOTE:** 1 gallon of Aquathol<sup>R</sup> contains 4.23 active ingredient.

$$\text{Acre feet} = \frac{150 \times 100}{43,560} \times 4 = 1.38$$

$$\text{ppm} = \frac{8.46 \text{ lbs} \times 453.6 \text{ gr/lb}}{1.38 \text{ acre ft} \times 43,560 \times 28.32 \text{ liters/ft}^3} = \frac{3837.46}{1,702,394.4} = .002 \text{ ppm}$$

c. **The Applicator's Job.** Modern aquatic herbicide labels do most of these calculations for the applicator. The applicator need only measure the lake or pond carefully and calculate acre feet, then use treatment charts provided on the label.

#### **7-47. CLOSING STATEMENT**

Careful planning is necessary to successfully manage aquatic weeds. The pest manager must consider a wide range of environmental and public health issues before implementing a control strategy. Detailed examination of the label, and careful calculations are needed when aquatic herbicides are used.

## EXERCISES, LESSON 7

**REQUIREMENT.** The following exercises are to be answered by selecting the correct letter, completing the incomplete statement, or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

1. List three types of damage caused by aquatic weeds.

a. \_\_\_\_\_

b. \_\_\_\_\_

c. \_\_\_\_\_

2. List the four growth habitats of aquatic weeds.

a. \_\_\_\_\_

b. \_\_\_\_\_

c. \_\_\_\_\_

d. \_\_\_\_\_

3. Two advantages of aquatic weed control by mechanical means are:

a. \_\_\_\_\_

b. \_\_\_\_\_

4. List five factors to be considered in designing an aquatic plant management program.

a. \_\_\_\_\_

b. \_\_\_\_\_

c. \_\_\_\_\_

d. \_\_\_\_\_

e. \_\_\_\_\_

**NOTE:** For test items 5 through 8, complete the statements about the environmental fate of these herbicides that are used to control aquatic plants.

5. Fluridone is broken down by \_\_\_\_\_; fluridone has a half-life of \_\_\_\_\_ days.

6. Dichobenil is broken down by \_\_\_\_\_, adsorption to \_\_\_\_\_, and volatilization; dichobenil has a half-life of \_\_\_\_\_ days.

7. Copper forms \_\_\_\_\_ with other elements or \_\_\_\_\_. Does copper breakdown? Yes / No. (cross out one.)

8. Diquat is taken up by \_\_\_\_\_ and adsorbed by \_\_\_\_\_. Diquat has a half-life of \_\_\_\_\_ days.

9. A major difference between flowering plants and ferns is reproduction. The difference is that \_\_\_\_\_

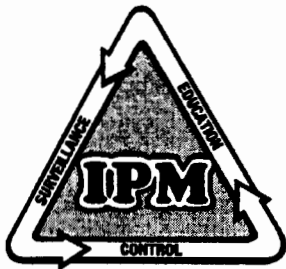
\_\_\_\_\_

\_\_\_\_\_

10. A pond has a surface area of 120,000 square feet and an average depth of 4 1/2 feet. How many acre feet of water does the pond contain?

11. The aquatic herbicide Aquathol<sup>R</sup> contains 4.23 pounds of active ingredient per gallon of concentrate. To treat a one mile canal which is five feet wide and two feet deep, at the rate of 2 ppm active ingredient, requires how much concentrate?

**END OF LESSON EXERCISES**



## SOLUTION TO LESSON EXERCISE TEST ITEM #11

11. **TEST ITEM.** The aquatic herbicide Aquathol<sup>R</sup> contains 4.23 pounds of active ingredient per gallon of concentrate. To treat a one mile canal which is five feet wide and two feet deep, at the rate of 2 ppm active ingredient, requires how much concentrate?

### SOLUTION.

**STEP 1.** Determine cubic feet.

$$5280 \times 5 \times 2 = 52,800 \text{ cubic feet}$$

**STEP 2.** Determine liters.

$$1 \text{ cubic foot} = 28.316 \text{ liters}$$

$$28.316 \times 52,000 = 1,495,084.8 \text{ liters}$$

**STEP 3.** Change liters to kilograms.

$$1 \text{ liter} = 1 \text{ kilogram}$$

$$1,495,084.8 \text{ liters} = 1,495,084.8 \text{ kilograms}$$

**STEP 4.** ppm = mg/kg.

Use this proportion:  $2 \text{ mg/kg} = X \text{ mg}/1,495,084.8 \text{ kg}$

$$X = \frac{2990169.6 \text{ mg}}{1,000,000 \text{ mg/kg}}$$

$$X = 2.99 \text{ kg}$$

**STEP 5.**

$$2.99 \text{ kg} \times 2.205 \text{ lbs/kg} = 6.59 \text{ lbs}$$

$$\frac{6.59 \text{ lbs}}{4.23 \text{ lbs/gallon}}$$

$$= 1.56 \text{ gallons Aquathol}^{\text{R}}$$

ANS.

(para 4-46)

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## LESSON ASSIGNMENT

### LESSON 8

- Fertilization.

### LESSON ASSIGNMENT

- Paragraphs 8-1 through 8-22.

### TERMINAL LEARNING OBJECTIVE

- Information gained in this lesson should enable you to understand the role of fertilizer in ensuring an adequate supply of nutrients to plants, the end goal being efficient crop production.

### SPECIFIC LESSON OBJECTIVES

- After completing this lesson, you should be able to:

#### 8-1. Identify the macro plant nutrient elements:

- ◆ Nitrogen.
- ◆ Phosphorus.
- ◆ Potassium.
- ◆ Calcium.
- ◆ Magnesium.
- ◆ Sulfur.

#### 8-2. Identify the following micro plant nutrient elements:

- ◆ Manganese.
- ◆ Iron.
- ◆ Copper.
- ◆ Boron.
- ◆ Chlorine.
- ◆ Molybdenum.
- ◆ Zinc.

#### 8-3. Identify the deficiency symptoms caused by a lack of specific soil nutrients.

#### 8-4. Identify the requirements for plant growth which are supplied by the soil.

#### 8-5. Define the following terms:

- ◆ Fertilizer.
- ◆ Complete fertilizer.
- ◆ Fertilizer grade.
- ◆ Acid-forming fertilizer.
- ◆ Non-acid-forming fertilizer.
- ◆ Fertilizer ratio.

### SUGGESTION

- After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 8

### FERTILIZER PROGRAM

#### Section I. PLANT MACRONUTRIENT ELEMENTS

##### 8-1. INTRODUCTION

a. **The Key to Reducing Pest Damage in Plants.** Management of pests affecting landscape plants requires more than a basic knowledge of pesticides. The key to reducing pest damage is plant health care which means keeping plants healthy enough to resist most pest infestations. One of the most important parts of plant health care is fertilization.

b. **Information in This Lesson.** In this lesson, we will discuss the nutrients needed for plant growth and consider some of the plant growth requirements supplied by the soil. Also discussed will be the various types of fertilizer now available and some of the terminology used in the fertilizer industry.

#### MACRONUTRIENTS

- ◆ Nitrogen
- ◆ Phosphorus
- ◆ Potassium
- ◆ Calcium
- ◆ Magnesium
- ◆ Sulfur

##### 8-2. NITROGEN (N)

a. **General Information.** One of the elements necessary for plant growth is nitrogen. Plants contain about one to five percent nitrogen by weight. Historically, animal manures were applied to the soil, and legumes were used in crop rotations to put nitrogen back into the soil. Low-cost synthetic nitrogen fertilizers have been produced, causing the use of manures and legumes to be less important, but still needed, in crop production.

b. **The Nitrogen Cycle.** Green plants, animals, and several kinds of bacteria are involved in the nitrogen cycle. The roots of plants absorb compounds of nitrogen combined with oxygen, sodium, and potassium. In green plants during photosynthesis, nitrogen combines with carbon, hydrogen, and oxygen. Sulfur and phosphorus are added. All these elements combine in the plants to form proteins.

- ◆ Animals need protein which they get by eating plants and other animals. The animals' digestive systems separate this protein into amino acids.
  - ◆ The amino acids combine to form another protein.
  - ◆ The animals' energy comes from the protein in the plants. When that energy is released, the animal excretes nitrogen wastes which go into the soil.
  - ◆ Bacteria in the soil or water breaks down the excreted waste even more.
  - ◆ Bacteria also breaks down dead organisms. Nitrogen from the decaying organism's protein combines with hydrogen to form ammonia.
  - ◆ Bacteria in the soil combines with the ammonia to form nitrites, which cannot be absorbed by plants.
  - ◆ Other types of bacteria in the soil combine with nitrites to form nitrates. These can be absorbed by plant roots, and, once again, nitrogen enters plants through their root systems.
  - ◆ Plants may also utilize the nitrogen from ammonia. Plants growing in acid soil may use ammonia nitrogen in preference to nitrate. Other plants grow faster with nitrate nitrogen.
- c. **Symptoms of Nitrogen Deficiency.**
- ◆ Plants may be stunted and yellow in appearance.

- ◆ Plant leaves which are severely deficient in nitrogen will turn brown and die. This deficiency will first occur in older leaves, young leaves remaining green.
- ◆ In grass, leaves die from the tip back. The lower leaves turn brown starting at the tip of the leaf and extending along its midrib. Finally, the entire leaf is dead.

### 8-3. PHOSPHORUS (P)

**a. General Information.** Phosphorus is essential for the growth of healthy plants. Phosphorus has many functions in plant life, but storing and releasing energy are its most important functions.

**b. Plants and Energy.** Plants produce energy through the photosynthetic process and through metabolizing carbohydrates.

- ◆ This energy is stored in the phosphate compounds adenosine diphosphate and adenosine triphosphate.
- ◆ Subsequently, plants use the stored energy for growth and reproductive processes.
- ◆ Adequate amounts of phosphorus are also necessary for seed formation associated with increased root growth.

**c. Results of Adequate Amounts of Phosphorus.** Adequate amounts of phosphorus are very beneficial to plant growth. Positive results include the following:

- ◆ Increased root growth.
- ◆ Greater strength of cereal straw.
- ◆ Improved quality of certain fruit, forage, vegetable, and grain crops.
- ◆ Increased tolerance of small grains to root-rot diseases.
- ◆ Decreased risk of winter damage to small grain crops.

### d. Symptoms of Phosphorus Deficiency.

- ◆ Overall growth reduction in plants.
- ◆ Leaves may appear dull green and/or purplish. (There is no striking color change.)

### 8-4. POTASSIUM (K)

**a. General Information.** Potassium is another element which is essential to healthy plant growth. It is usually found in plants in concentrations of from one to four or five percent. Although potassium exists in the soil in several forms, only a small portion of that potassium is available to plants. And, plants require a large amount of potassium.

**b. Functions of Potassium in Plants.** The functions of potassium in plants can be divided into these six areas:

- ◆ Enzyme activation. Potassium is necessary for the activation of over 60 enzymes, enzymes that are part of plant physiological processes.
- ◆ Water relations. Potassium provides some of the osmotic pull which draws water into the roots of plants.
- ◆ Energy relations. Potassium is necessary in the process of photosynthesis and the formation of phosphate compounds,
- ◆ Translocation of assimilates. Potassium is necessary for transportation of plant sugars to the parts of the plants where the sugars will be stored or used for growth.
- ◆ Nitrogen uptake and protein synthesis. Nitrogen uptake and plant synthesis in plants require the presence of potassium.
- ◆ Starch synthesis. For starch synthesis to occur, potassium in adequate supply must be present.

**c. Symptoms of Potassium Deficiency.** Included are the following:

- ◆ The first symptom appears in leaf development. The leaves may be yellow and streaked.
- ◆ A symptom in grain crops is the weakening of straw.
- ◆ Reduced crop yields can be caused by insufficient potassium.
- ◆ Also possible is decreased resistance to certain fungal plant diseases such as powdery mildew, stem rusts, and stalk rots.

**8-5. CALCIUM (Ca)**

**a. General Information.** All higher plants require the element calcium. Calcium, usually abundant in leaves, has a normal concentration of from 0.2 to 1.0 percent in plants. This element is essential for cell elongation and division and for the growth and development of cell membranes.

**b. Symptoms of Calcium Deficiency.**

- ◆ Growth reduction.
- ◆ Fruit and vegetable disorders.
- ◆ Reddish-brown leaf discoloration, fading to red, withered leaf tips.

**8-6. MAGNESIUM (Mg)**

**a. General Information.** Magnesium, located at the center of the chlorophyll molecule, is usually found in plants in a concentration of from 0.1 to 0.4 percent. Magnesium's importance is that it is the only mineral in the chlorophyll molecule, chlorophyll being necessary for photosynthesis in green plants.

**b. Functions of Magnesium in Plants.** Included are the following:

- ◆ Magnesium is needed for maximum activity of many enzyme systems.
- ◆ Magnesium can move from one part of a

plant to another part if needed to correct a deficiency.

**c. Symptoms of Magnesium Deficiency.** Note these symptoms:

- ◆ The leaves turn yellow with the veins remaining green.
- ◆ Lower leaves in some plants, such as cotton, turn reddish-purple, then brown, and finally necrotic.
- ◆ Symptoms may first occur in young leaves.

**NOTE:** Plant growth may be affected by the balance of calcium, magnesium, and potassium in the soil—if there is a gross imbalance.

- ◆ The level of exchangeable magnesium should be between 15 and 50 percent of the level of calcium.
- ◆ Potassium should make up two to five percent of the exchangeable cations.

**8-7. SULFUR (S)**

**a. General Information.** Sulfur, found in a concentration ranging from 0.1 to 0.4 percent by weight, is absorbed primarily by plant roots.

- ◆ Low levels of sulfur are absorbed through plant leaves.
- ◆ This element is necessary for plant synthesis of other essential compounds such as vitamins, enzymes, and proteins.

**b. Symptoms of Sulfur Deficiency.** Included are the following:

- ◆ Pronounced reduction of plant growth.
- ◆ Uniform yellowing of leaves of plants.

## Section II. PLANT MICRONUTRIENT ELEMENTS

### MICRONUTRIENTS

- ◆ Manganese
- ◆ Iron
- ◆ Copper
- ◆ Boron
- ◆ Chlorine
- ◆ Molybdenum
- ◆ Zinc
- ◆ Cobalt
- ◆ Vanadium
- ◆ Sodium
- ◆ Silicon

#### 8-8. MANGANESE (Mn)

a. **General Information.** Manganese, a transition metal required for plant growth and development, is normally found in plants in the range of 20 to 500 ppm. Manganese is involved in the process of photosynthesis. This element is required for maximum activity of many enzyme systems and may be absorbed by plants from foliar sprays. Excessive amounts of manganese are toxic to plants.

b. **Symptoms of Manganese Deficiency.** Included are the following:

- ◆ Interveneal yellowing with the leaf veins staying green.
- ◆ Necrotic leaf spots with symptoms occurring first in young leaves.

#### 8-9. IRON (Fe)

a. **General Information.** Iron is involved in the photosynthesis and respiration process of plants and is a cofactor in enzymatic reactions. Seventy-five percent of the total iron in plants is in chloroplasts. Normal iron concentrations range from 50 to 250 ppm. Iron is associated with a dark green color in plants. Iron deficient plants will regain this green

color within hours after a liquid iron fertilizer is applied.

b. **Symptoms of Iron Deficiency.**

- ◆ Interveneal chlorosis in young leaves.
- ◆ Leaves may turn white.

#### 8-10. COPPER (Cu)

a. **General Information.** Copper is an essential part of plant enzyme systems with normal concentrations in the range from 5 to 20 ppm. This element cannot be replaced by any other metal ion.

b. **Symptoms of Copper Deficiency.** Deficiencies are most common in peat or muck soils (because the highly organic soils do not retain sufficient copper). The symptoms vary with the crop as noted below:

- ◆ Corn. Youngest leaves become stunted and yellow.
- ◆ Vegetable crops. Leaves have an initial bluish cast. The leaves then yellow or bleach out and curl along the edges. Flowers are not produced and the crop fails, or, if flowers are produced, they are pale, small, and misshapen.
- ◆ Small-grain plants. Younger leaves lose color and eventually break, tips die.

#### 8-11. BORON (B)

a. **General Information.** Adequate amounts of boron are essential for new cell development in plants. The adequate range of boron concentration is from 6 to 18 ppm. This element plays a role in the translocation of sugars, starches, nitrogen, and phosphorus in plants. Boron also aids in the synthesis of amino acids and proteins as well as regulating the metabolism of carbohydrates in plants.

b. **Symptoms of Boron Deficiency.**

- ◆ Thickened, wilted, or curled leaves.
- ◆ Thickened, cracked, or water-soaked petioles and stems.

- ◆ Growth point stunted.
- ◆ Leaves with one-sided or twisted appearance.
- ◆ Young leaves pale green or may blacken and shrivel.

#### 8-12. CHLORINE (Cl)

**a. General Information.** Chlorine is essential for plant growth. The concentration range in plants is from 0.2 to 2.0 percent but may be as high as 10 percent. Chlorine seems to be a biochemically inert element which does not enter into metabolic reactions. Chloride ions may neutralize positively charged ions (cations) in the cells, increasing osmotic potential within cells.

##### **b. Essential Functions.**

- ◆ Osmotic potential.
- ◆ Disease control.

**c. Symptoms of Chlorine Deficiency.** Included are the following:

- ◆ Chlorosis in younger leaves.
- ◆ Overall wilting.
- ◆ Necrosis and leaf bronzing.

#### 8-13. MOLYBDENUM (Mb)

**a. General Information.** Plants absorb molybdenum in relatively large amounts without any apparent toxicity. The normal concentration of molybdenum in dry plant matter is less than 1 ppm. Molybdenum is mostly found in the enzyme nitrate reductase in legumes. This element is a component of nitrogenase, the enzyme involved in nitrogen fixation.

**b. Symptoms of Molybdenum Deficiency.** Deficiencies of this element are often found in the acid, sandy soils along the Atlantic and Gulf coasts. Crops sensitive to molybdenum deficiency include legumes, crucifers, citrus fruits, and crops such as beets, lettuce, spinach, sweet potatoes, and tomatoes. Signs of deficiency include:

- ◆ Interveinal chlorosis on older, lower leaves.

- ◆ Stunting, withering, and leaf necrosis.

#### 8-14. ZINC (Z)

**a. General Information.** Zinc, an element absorbed in various forms through roots and leaves, is usually found in plant dry matter in a concentration range of 25 to 150 ppm. Zinc is toxic in concentrations above 400 ppm. Zinc's availability to plants is affected by many soil and environmental factors; for example, absorption on clay surfaces, organic matter, carbonates and oxide materials; interactions with other nutrients; and climatic conditions.

**b. Symptoms of Zinc Deficiency.** To correct the widespread deficiency of zinc in the United States, one or more crops in many states require the application of supplemental zinc. Symptoms of zinc deficiency include:

- ◆ Light green, yellow, or white mottling between the veins of leaves.
- ◆ Stunted growth.
- ◆ Shriveled and desiccated leaves.

### Section III. PLANT GROWTH REQUIREMENTS

#### 8-15. SOIL STRUCTURE AND COMPOSITION OF SOIL AIR

The roots and the top growth of plants are influenced by the structure of the soil in which they exist. If the soil is compact, pore space and soil oxygen are reduced. Adequate pore space is necessary for root growth; adequate soil oxygen is required for root respiration. If neither pore space or soil oxygen are adequate, the result is reduced growth and eventual death of plants.

#### 8-16. SOIL REACTION

**a. Measurement of Soil Reaction.** Soil reaction (soil acidity) is measured by pH. The pH scale measures the relative

concentration of hydrogen ions ( $H^+$ ) and hydroxyl ions ( $OH^-$ ).

- ◆ In pure water, the concentration of hydrogen and hydroxyl ions are equal. So in one liter of water,  $1 \times 10^7$  molecules have split into hydrogen and hydroxyl ions.
- ◆ The pH of pure water is written as the reciprocal of the logarithm of the hydrogen ion concentration, so  $1 \times 10^{-7}$  becomes pH 7.
- ◆ If the concentration of hydrogen ions increases to  $1 \times 10^{-6}$ , the pH is written as 6.
- ◆ Since pH 7 is neutral, values below 7 are acid (higher relative concentration of hydrogen ions), and values above 7 are alkaline (smaller relative concentration of hydrogen ions).

#### **b. Plant Growth and Soil pH Level.**

Soil acidity doesn't directly affect plant growth. The pH does affect the availability of plant nutrients. Plant growth is generally optimum at a pH level of 6.5. Nutrients are available in adequate quantity at this pH, but not at toxic levels. Beneficial soil microorganisms thrive in slightly acid soils.

- ◆ Examples of the effect of pH include the low availability of phosphorus in acid soils. In acid soils, phosphates may precipitate or bind to other substances in an unusable form. Manganese is unavailable in high pH soils.
- ◆ The micronutrient molybdenum becomes unavailable in low pH soils.
- ◆ Plants may be poisoned in low pH soils. Manganese can be released into soil water in toxic amounts (if sufficient manganese is present), and toxic levels of aluminum may be released as the pH continues to drop.
- ◆ Adding calcium to soil raises the pH level. Adding sulfur to soil lowers the pH level.

### **8-17. MINERAL NUTRIENT ELEMENTS**

**a. General Information.** Mineral nutrients compose about 5 to 10 percent of the dry weight of plants. These nutrients (nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron, chlorine, copper, iron, manganese, molybdenum, and zinc) are absolutely essential to plant growth and development. Each of these nutrients is obtained from the soil.

**b. Colloidal Fractions.** Soil nutrient levels are affected by the amount of clay and organic matter in the soil. These soil fractions are called the colloidal fractions. The term "colloid" refers to the ability of clay or organic matter to stay suspended in pure water.

- ◆ Colloidal materials have a huge surface area because of the tiny (less than 0.002mm diameter) particle size.
- ◆ Colloid particles also carry a negative charge, which attracts and holds positively charged ions (or cations).
- ◆ The main cations affecting plant nutrition are  $H^+$ ,  $Al^{3+}$ ,  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $K^+$ ,  $NH_4^+$  and  $Na^+$ .
- ◆ Soils with high levels of organic material and clay are said to have high cation exchange capacity (because the cations often swap places with cations in the soil water).
- ◆ Most soil particles carry a positive charge, so the negatively charged colloids are crucial to plant nutrition.

**c. Fertilization.** Fertilization is the process of adding supplemental nutrients to soil to encourage plant growth. Modern agricultural and landscaping practices are completely dependent on fertilization.

### **8-18. MOISTURE SUPPLY**

**a. Plant Growth and Soil Water.** Plant growth is often in direct proportion to the amounts of available soil water. Plant growth is restricted at very low and very high levels. Water is necessary for a variety of metabolic activities in plants, such as the manufacture of

carbohydrates. Water is the main component of protoplasm. Water is a medium for the translocation of foods and mineral nutrients. Insufficient water reduces plant cell division and cell elongation, so plant growth is reduced under moisture stress.

**b. Plants and Moisture Stress.**

Plants constantly lose water through transpiration and replace the losses by extracting soil water. Moisture stress results when the rate of transpiration exceeds the available moisture in the plant root zone.

- ◆ Plant growth (and thus the yield of agricultural crops) is affected by moisture stress, but the quality of crops is also affected. For example, the protein content of grain is influenced by the quantity of available water.

**c. Plants and Soil Nutrients.** Plants cannot effectively take up nutrients from the soil unless soil moisture levels are adequate.

- ◆ Because plants can take up nutrients more readily as soil moisture levels increase, the efficiency of water use (related to crop yield) is increased in moist soils.

**d. Fertilizer Placement.** Fertilizer placement must be carefully considered when the upper soil levels are subject to quick drying. In this situation fertilizer must be placed in the plant's lower root zone, because fertilizer nutrients will not be taken up from the dry surface soil.

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**Section IV. TERMINOLOGY/  
SOIL TESTING**

**8-19. FERTILIZER TERMINOLOGY**

Become familiar with these terms:

- ◆ Fertilizer. Substance, containing one or more plant nutrients, which is used for plant nutrient content.

- ◆ Complete fertilizer. A fertilizer containing nitrogen, phosphorus, and potassium.
- ◆ Fertilizer grade. Minimum guarantee of plant nutrient content in terms of total nitrogen, available phosphorus pentoxide, and soluble potassium oxide; example, 6-12-12.
- ◆ Fertilizer ratio. Relative percentage of nitrogen, phosphorus pentoxide (P, and potassium oxide; example, a 6-12-12 grade has a 1-2-2 ratio.
- ◆ Acid-forming fertilizer. Increases acidity of the soil, lowering the pH.
- ◆ Non-acid-forming fertilizer. Leaves neither acidic nor basic residue in the soil.
- ◆ Slow-release fertilizer. Fertilizers designed to control and prolong the release of nutrients over a period of time. These fertilizers are formulated by coating fertilizer granules with resin or plastic; coating granules with sulfur and binding agents; or using fertilizers materials which are naturally slow to dissolve, such as organic materials, urea formaldehyde, or IBDU (Isobutylidene diurea).

**8-20. SOIL TESTING**

**a. Purpose of Soil Testing.** Soil testing is a chemical (as opposed to the visual methods of early agriculture) method for estimating the fertility of soil.

- ◆ A soil test measures part of the total nutrient content of a particular soil. These values are meaningless alone.
- ◆ Extensive field and greenhouse testing have established the relation between soil nutrient values and plant growth.
- ◆ Soil scientists can now predict plant growth based on soil test results.

- ◆ Soil testing laboratories use this information to determine "low," "medium," or "high" nutrient levels in soil.

#### **b. Objectives of Soil Testing.**

- ◆ To build up the fertility of a given area of land, or to maintain the fertility of an already productive field.
- ◆ To predict the response of crop plants to a given application of lime or fertilizer.
- ◆ To determine the proper amount of lime or fertilizer to apply.
- ◆ To evaluate the fertility of soils over a large land area (such as a military base.)

**c. Basic Purpose.** In simple terms, the objective of soil testing is to obtain a value which may be used to predict the amount of fertilizer to apply.

#### **8-21. SAMPLING TECHNIQUE FOR SOIL TESTING**

- ◆ Soil tests are useless unless the soil sample is representative of the land area being tested.
- ◆ Follow these guidelines to sample soil:
  - Take 12 to 15 samples from each uniform area.
  - Keep samples approximately 1 inch in diameter and 2 to 4 inches deep.
  - Remove thatch and turf from the sample.
  - Be sure the sample is thoroughly mixed.
  - Test the soil every one to four years, depending on the soil type and the intensity of the culture.

- Intensively managed soils (such as golf courses) should be sampled at least once and probably twice a year.

#### **8-22. CLOSING**

Many specialists in landscape maintenance believe plant care is essentially care of the soil. Understanding the principles of soil fertility is the first step toward proper plant maintenance and management of plant pests.

## EXERCISES, LESSON 8

**REQUIREMENT.** The following exercises are to be answered by selecting the correct letter, completing the incomplete statement, or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

1. List four plant macronutrient elements.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_

2. List six plant micronutrient elements.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_
- f. \_\_\_\_\_

3. Plant leaves severely deficient in nitrogen will \_\_\_\_\_

4. Calcium deficiency can cause leaves to turn reddish-brown and fade to \_\_\_\_\_

5. Sulfur deficiency causes plant leaves to \_\_\_\_\_

6. Manganese deficiency causes yellowing between leaf veins while the veins themselves are \_\_\_\_\_ colored.

7. Plants suffering from a deficiency of boron may have young leaves which are pale green or which \_\_\_\_\_

8. Fertilization may be defined as the process of \_\_\_\_\_

9. A fertilizer which increases the acidity of the soil, thus lowering the pH is termed \_\_\_\_\_

10. A fertilizer containing nitrogen, phosphorus, and potassium is called \_\_\_\_\_

11. The basic objective of soil testing is to \_\_\_\_\_

12. A soil test is useful only if \_\_\_\_\_

**END OF LESSON EXERCISES**



## LESSON ASSIGNMENT

<b>LESSON 9</b>	— Identification and Control of Tree and Ornamental Plant Diseases.
<b>LESSON ASSIGNMENT</b>	— Paragraphs 9-1 through 9-14.
<b>TERMINAL LEARNING OBJECTIVE</b>	— Information gained in this lesson should enable you to employ integrated pest management principles to control plant diseases IAW the <i>Integrated Pest Management for Turf and Ornamentals</i> , 1994, Ed. Anne R. Leslie, and <i>Plant Pathology</i> , 3rd edition, 1988, George N. Agrios.
<b>SPECIFIC LESSON OBJECTIVES</b>	— After completing this lesson, you should be able to:  9-1. Select the three conditions necessary for a plant disease to occur.  9-2. Select the five causal agents of plant diseases.  9-3. Select the environmental conditions which may cause plant damage.  9-4. Select the modes for spreading plant diseases.  9-5. Identify the major groups of plant pathogens.
<b>SUGGESTION</b>	— After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 9

### IDENTIFICATION AND CONTROL OF TREE AND ORNAMENTAL PLANT DISEASES

#### Section I. INTRODUCTION

#### 9-1. GENERAL INFORMATION

Landscape plants are usually chosen and cultivated because of their appearance, so management of diseases is particularly important. Many plant diseases do not pose any serious threat to plant health, but even an innocuous leaf spot disease is unattractive and

undesirable in a landscape specimen. Chemicals may be used to quickly eliminate an unattractive disease which would never be noticed in a forestry situation.

##### a. Susceptibility to Disease.

Landscape plants are also more susceptible to many diseases than woody plants growing in a natural setting. This is the result of poor site selection and the environmental stresses of urban or suburban landscapes, including:

- ◆ Soil compaction.
- ◆ Pruning and trimming.
- ◆ Excessive light.
- ◆ Drought.
- ◆ Low fertility.

b. **Resistance.** Plants under environmental stress grow more slowly and heal wounds more slowly than similar plants in a natural setting. Healthy plants may resist a disease which overcomes a stressed or damaged plant.

## 9-2. DEFINITION OF PLANT DISEASE

Plant disease may be defined as a malfunctioning of host cells and tissues that results from their continuous irritation by a pathogenic agent or environmental factor and leads to the development of symptoms.

## Section II. INFECTIOUS DISEASES

### 9-3. REQUIREMENTS FOR INFECTIOUS PLANT DISEASE TO OCCUR

Three conditions must be met before a plant disease can occur.

a. **Susceptible Host Plant.** Not all woody plant species are susceptible to the same diseases. In fact, most diseases are very host-specific. Even within a species, there is a wide range of resistance to the same disease organisms. Plant breeders and pathologists have developed and identified a number of disease resistant cultivars (cultivated varieties) of woody species, which can be used to minimize plant disease problems. Many of these cultivars are not immune to the disease, but infection levels are low enough to preclude the need for pesticides.

b. **Favorable Environment.** Many pathogens only occur in specific environmental conditions, such as heavy shade, high humidity, or damaged tree bark. However, most pathogens are parasites, obtaining nourishment from the host plant, and the environment is often not a limiting factor for plant disease occurrence.

c. **Pathogen or Causal Organism.** Many pathogens survive the winter on leaves which were infected and shed the previous year. Other pathogens survive in twigs and branches.

The quantity of pathogens can sometimes be reduced by sanitation, corrective pruning and other methods.

## Section III. CAUSAL AGENTS OF INFECTIOUS DISEASES

### CAUSAL AGENTS OF INFECTIOUS PLANT AND ORNAMENTAL TREE DISEASES

- ✓ Bacteria.
- ✓ Fungi.
- ✓ Viruses and viroids.
- ✓ Nematodes.
- ✓ Parasitic plants.

### 9-4. BACTERIA

a. **General Information.** Bacterial diseases of plants are fairly rare, but may be extremely severe and rapid. Bacteria are microscopic, single-celled organisms with rigid cell walls. These organisms reproduce by binary fission, which means one bacteria divides into two cells. This division may occur every 30 minutes, so reproduction can be extremely rapid when conditions are favorable for bacterial growth. Bacteria enter plants through wounds and natural openings such as stomata.

b. **Damage.** Plant pathogenic bacteria destroy plant tissue by producing toxins and enzymes. The toxins are probably a by-product of bacterial growth; the enzymes are used to

break down plant tissues during feeding. The damage caused by bacteria includes:

- ◆ Leafspots. Bacterial leafspots are often limited by large leaf veins, so angular leafspots (caused by the angle of the vein) on dicotyledons may indicate a bacterial pathogen. Bacterial leafspots on monocots may appear as stripes, because the leaf veins are parallel. The spot will be necrotic and is often surrounded by a yellowish halo.
- ◆ Blights. A blight is a rapidly advancing area of necrotic tissue on leaves, stems, flowers, or fruits. Many times, the final stage of a leafspot disease appears as a blight.
- ◆ Vascular Wilts. A wilt occurs when bacteria invades the xylem tissue of a plant and multiplies. The bacteria interrupt the flow of water and dissolved minerals to leaves by mechanical blockage or by dissolving xylem cell wall substances, and this causes wilting and eventual death.
- ◆ Soft-Rots. A soft rot occurs when bacteria enter plant tissue (usually through wounds) and multiply in the intercellular spaces. The enzymes produced by the bacteria soften and decay plant tissue.
- ◆ Galls and Tumors. These symptoms occur when gall-inducing bacteria enter plants through wounds and stimulate plant cells to divide and enlarge. The disease crown gall is unique because the gall is malignant. The stimulated plant cells continue to divide until the plant is killed or the gall can no longer obtain nutrients.

**c. Dissemination.** Bacterial diseases are spread in a variety of ways.

- ◆ The pathogens may be moved in contaminated soil, compost, or in flowing rainwater.

- ◆ Some bacteria are moved by splashing rain. Because many bacterial diseases result in a bacterial ooze on the exterior of the plant, the pathogens are easily washed off during a rainstorm.
- ◆ Planting diseased nursery stock may introduce a bacterial disease into a new area.
- ◆ Tools used to prune infected plants must be decontaminated prior to pruning healthy plants, or the disease can be spread via the tools.
- ◆ Insects spread bacterial diseases from plant to plant during feeding.



#### THE SPREAD OF BACTERIAL DISEASES

- ✓ In contaminated soil or compost.
- ✓ In flowing rainwater.
- ✓ By splashing rain.
- ✓ In plant-diseased nursery stock.
- ✓ By contaminated tools.
- ✓ From plant to plant, during feeding.

#### d. Control.

(1) Cultural control. Cultural control is control without the use of chemicals. Some controls effective against bacterial diseases are resistant cultivars, pruning, fertilization, and watering.

- ◆ Resistant cultivars. Select plants that have been cultivated to be resistant to bacteria found in the local area.
- ◆ Pruning. Pruning is removing and destroying contaminated plants or plant parts. This effective method of control must be combined with careful sterilization practices to avoid spreading the disease on tools. Pruning is effective against fire blight, which is one of the most serious bacterial diseases.

- ◆ Disease-free seed and transplants. Nursery stock should be carefully inspected to prevent planting an already diseased ornamental.

- ◆ Fertilization and watering. Fertilization and watering are used to maintain the health of ornamental trees and shrubs.

- In general, most landscape specimens, particularly trees, are drought stressed. This is because of inadequate root space, compacted soil, and competition from turfgrass and other understory plants.
- Proper fertilization and deep watering (along with efforts to break up compacted soil) maintain plant health and allow maximum plant resistance to disease.

(2) Antibiotics. Antibiotics such as streptomycin or tetracycline may be sprayed on woody plants or injected into the xylem tissue. Antibiotics are effective against bacterial disease, but the cost may be prohibitive except with valuable specimens.

(3) Soil Fumigants. Soil fumigants may be used to sterilize soil which is believed to be contaminated with bacterial diseases.

## 9-5. FUNGI

**a. General Information.** Fungi are believed to cause 80 to 85 percent of all plant diseases. Most diseases of trees and woody ornamentals are caused by fungus. Fungi are plant-like organisms with no chlorophyll, but current biological classifications place fungi in a separate kingdom, Mycetae, neither plant or animal. Fungi reproduce by spores (minute propagating structures with no embryo). Spores may be sexual or asexual. The spores of lower fungi are motile.

**b. Damage.** Fungi live as parasites or saprophytes on host plants.

- ◆ The damage caused by fungi include tissue necrosis, stunting of plant organs or entire plants, and excessive growth of plant parts.

**c. Symptoms.** Symptoms on woody plants include rusts, leafspots, cankers, root rot, basal stem rot, galls, and clubroot.

- ◆ Rusts. Rusts may be defined as many small lesions on leaves or stems. Usually the lesions are rust colored.
- ◆ Leafspots. Leafspots are localized lesions caused by dead and collapsed cells.
- ◆ Cankers. Cankers are localized wounds or lesions on the stem.
- ◆ Root rot. Root rot is decay of part or all of the root system.
- ◆ Basal stem rot. Basal stem rot is decay of the lower part of the stem.
- ◆ Galls. Galls are enlarged parts of plants, usually filled with fungus mycelium.
- ◆ Clubroot. Clubroot may be defined as enlarged roots looking like spindles or clubs.

**d. Dissemination.** Almost all plant pathogenic fungi spend part of their life cycle on the parasitized plant, and part in the soil or in dead plant tissue on the soil.

- ◆ Because spores are very light and easily airborne, the wind is probably the most important mechanism for fungus dissemination.
- ◆ Specific fungi may be spread by other mechanisms such as splashing or flowing water, blowing dust, insects, farm equipment, infected tools, or plant materials.



## THE SPREAD OF FUNGAL DISEASES

- ✓ The wind.
- ✓ Splashing or flowing water.
- ✓ Blowing dust.
- ✓ Insects.
- ✓ Farm equipment.
- ✓ Infected tools or plant materials.

### e. Control.

(1) Cultural control. New plantings should be designed to avoid future problems with fungal disease. There are several steps which are effective at prevention of fungal disease. Some of these are as follows:

- ◆ Plant Selection. Select cultivars and plant species that are resistant to disease. Use similar but not those plants with documented disease problems. If you must use a species with disease problems, select disease-resistant cultivars.
  - ◆ Site Selection. Landscape planners must evaluate the soil, drainage, pedestrian and vehicular traffic, air flow, and other factors, with an eye to plant stress and disease potential. Most species of fungus which attack woody ornamentals, particularly the devastating diseases which attack the bark, cortex, and vascular cambium, are facultative parasites. This means the fungus can live as a saprophyte, but takes advantage of a favorable environment to parasitize living plants.
  - ◆ Sanitation. Many fungus diseases survive during the winter in infected leaves. Reduce this problem by collecting and destroying infected leaves in the fall. If there are infected twigs and branches, remove them also reduces the opportunity for fungus diseases to spread.
- ◆ Plant Care. Plants in urban areas need special care; dry and compacted soil are negative characteristics of the urban environment. Such conditions weaken plants and increase susceptibility to fungus diseases. Special care involves watering plants and aerating the soil toward the goal of enhancing plants' natural resistance to disease.
  - ◆ Pruning. To prevent disease, pruning should only be used for a well-defined purpose, and the cuts should be made when the plant can quickly repair the damage.
    - Most woody landscape plants are pruned to maintain shape, remove broken or misshapen branches, or reduce the risk of breakage.
    - Pruning cuts, the creation of plant wounds, makes plants vulnerable to attack from wood decay and canker-forming fungus.
    - Plants form a barrier zone after they are cut (pruned). During a period of rapid growth, the barrier zone forms quickly.
    - On the other hand, a dormant plant that is cut does not form a barrier zone. Therefore, prune when plants are growing rapidly—probably early spring to midsummer.
    - The disease oak wilt is the exception to pruning in spring to midsummer. Wounds in oak trees attract insects in spring and early summer, the insects then transmitting the disease to other oak trees.
    - Make pruning cuts at the branch "collar" or the natural junction between a stem and a branch.
- (2) Chemical control.
- ◆ Surface active fungicides. Apply these chemicals to foliage to control germinating spores. These fungicides

are effective for at least 10 to 14 days, and have a broad spectrum of control.

- ◆ Surface active and locally systemic fungicides. Plants absorb these chemicals through the leaf epidermis. The chemical, then, controls spore germination and some plant infections. Some of these fungicides control fungus by inhibiting the formation of organic compounds called sterols.
- ◆ Systemic Fungicides. Systemic fungicides can move within a plant. As they move, they can control existing infections. The fungicides can be injected into tree trunks or applied to foliage or soil.
- ◆ Other materials. Such leaf diseases as powdery mildew and black spot of rose have been controlled by baking soda. Powdery mildew has also been controlled by polymer coatings, a material which reduces plant transpiration.

(3) Biological. Fungal diseases are not usually controlled biologically. Current theory is that nonpathogenic fungus which will protect plant tissue against pathogens.

- ◆ For example, the theory is that applying *Agrobacterium radiobacter* as a root dip or drench will prevent crown gall in susceptible species. Or, apply a formulation of *Trichoderma* spp. to fresh wounds in order to prevent wood decay and canker diseases.
- ◆ With research, new products for the control of fungal disease will probably appear in the future.

## 9-6. VIRUSES AND VIROIDS

a. **General Information.** Viruses are noncellular, ultramicroscopic particles which multiply only in living cells. Viruses usually consist of a protein shell surrounding nucleic acid (usually RNA), while viroids consist of nucleic acid with no protein shell. Viruses and viroids

have no motility, and normal infections often are the result of the introduction of the pathogen to the host by insect feeding and nematode feeding activity.

b. **Damage.** Damage from viruses and viroids includes reduced plant size, yellowing, a pattern of light and dark green areas on leaves (mosaic pattern), and tissue death.

c. **Dissemination.** Virus and viroid particles must contact a wounded living cell. Transmission may occur as a result of:

- ◆ Insect feeding activity.
- ◆ Nematode feeding activity.
- ◆ Vegetative propagation: budding, grafting, cuttings, tubers, bulbs, or rhizomes.
- ◆ Parasitic plants.
- ◆ Seed or pollen.



### THE SPREAD OF VIRUS AND VIROID DISEASES

- ✓ By insect feeding activity.
- ✓ By nematode feeding activity.
- ✓ Through vegetative propagation.
- ✓ By parasitic plants.
- ✓ Through contaminated seed or pollen.

## d. Control.

(1) Cultural control. Nonchemical control can be achieved through the methods listed below.

- ◆ Use resistant varieties.
- ◆ Obtain certified, virus-free seed and transplants.
- ◆ Control weeds (which may be virus reservoirs).

- ◆ Destroy infected plants (to prevent insect or nematode transmission).

(2) Chemical control. Currently, there are no chemicals available for the control of viruses and viroids.

## 9-7. NEMATODES

**a. General Information.** Nematodes are soft bodied, transparent, tubular worms. They range in size from 1/50 to 1/4 inch (0.5 to 6mm long). Most plant parasites are less than 2 mm.

- ◆ Nematodes may be extremely abundant: 100,000 nematodes have been isolated from one liter of garden soil.
- ◆ Most are free-living and consume microorganisms, but several hundred species have been identified as plant parasites.
- ◆ Nematode plant parasites feed through a stylet, a tiny hypodermic-like needle. They use the stylet to suck cytoplasm from plant cells and to inject liquids into the cells.
- ◆ There are two types of plant nematodes: endo-parasites and ecto-parasites.
  - Endo-parasites. Endo-parasites live and feed within the plant roots.
  - Ecto-parasites. Ecto-parasites feed on roots (or other plant parts) from outside the plant.

**b. Damage.** Nematodes injure plants as a direct result of their feeding activity or as a result of toxic materials they inject into plant tissues. They may also serve as vectors for some other infectious agents such as viruses. Symptoms of nematode damage include plant stunting, loss of plant vigor, wilting, root knots, and die back.

**c. Dissemination.** Nematodes may be spread through infected plant material, soil, machinery, tools, drainage or irrigation water, and strong winds (which carry dust).



## THE SPREAD OF DISEASES BY NEMATODES

Diseases spread by nematodes being in:

- ✓ Infected plant material.
- ✓ Infected soil.
- ✓ Infected machinery and tools.
- ✓ Infected drainage or irrigation water.
- ✓ Strong, infected dust-carrying winds.

## d. Control.

(1) Cultural control. Methods of cultural control include using:

- ◆ Resistant cultivars.
- ◆ Nematode-free transplants and soil.
- ◆ Crop rotation.
- ◆ Hot water or steam soil injection.

(2) Chemical control. Chemical control can be achieved through nematicides injected into the soil or used as a dip for transplants. Additionally, soil fumigation before planting has proven helpful.

## 9-8. PARASITIC PLANTS

**a. General Information.** Mistletoes and dwarf mistletoes are parasitic plants that live on and damage healthy plants. They take all of their nourishment (water, minerals, and organic compounds) from the host tree.

- ◆ Mistletoes. Mistletoes are shrubby green plants that parasitize hardwood trees such as elm, hackberry, silver maple, oak, birch, and Modesto ash. Some conifers are also attacked.
- ◆ Dwarf mistletoes. Dwarf mistletoes are small, leafless green plants that parasitize cone bearing trees. They are among the most damaging forest pathogens in North America.

**b. Damage.** Heavy infestations of the mistletoes and dwarf mistletoes cause a loss of plant vigor, reduced growth, distorted trunks, large knots, and dead branches. Damage may be aesthetic, or it may be economic as a result of reduced timber value.

**c. Dissemination.** The mistletoes are spread mainly by birds and rodents. Dwarf mistletoes are spread by projectile seed discharge.



#### THE SPREAD OF PARASITIC PLANTS

- ✓ Mistletoes: spread by birds and rodents.
- ✓ Dwarf mistletoes: spread by projectile seed discharge.

#### **d. Control.**

(1) Cultural control. Cultural control can be achieved by pruning, at least 30 cm behind the shoots. Repeatedly breaking off shoots is another method. A third method is removing badly infested plants.

(2) Chemical control. Herbicides may be effective, but should be applied while the host tree is dormant. You should be aware that herbicides may injure or kill the host tree.

### Section IV. NONINFECTIOUS DISEASES.

#### **9-9. GENERAL INFORMATION**

Ornamental plants are also susceptible to damage and disease from noninfectious causes. Environmental stresses are natural causes. Misapplication of pesticides is an example of damage from human activity. The direct injury to

plants may be significant, but greater damage is reduced plant vigor and resistance to infectious agents.

#### **9-10. NUTRIENT DEFICIENCIES.**

Of the 20 nutrients considered essential for the growth of healthy plants, all are normally supplied by soil except carbon, hydrogen, and oxygen. Essential nutrients and their deficiencies include the following problems to vegetation:

**a. Nitrogen.** Insufficient nitrogen results in slow growth, reduced leaf size or number of leaflets on compound leaves, and subnormal synthesis of chlorophyll which results in general pale green color or chlorosis. Old leaves usually show these signs more severely than young leaves.

**b. Phosphorus.** Deficiency results in poor plant growth. Leaves may have abnormal reddish-purple spots. However, there may be no noticeable reduction in leaf density. Seedlings exhibit slowed development and have thin, spindly shoots.

**c. Potassium.** Insufficient potassium results in thin shoots, slow growth, and possible die-back. Foliage may be generally sparse, and older leaves show chlorosis and browning of tips.

**d. Other Nutrients.** Plants also require a number of secondary elements for proper growth, and deficiencies in these can cause a variety of symptoms.

#### **9-11. ENVIRONMENTAL DAMAGE**

Both man-made and natural environmental conditions can have an adverse effect on ornamental plants.

**a. Misapplied Pesticides.** Properly applied pesticides have a maximum impact on target species while having a minimal effect on nontarget organisms.

- ◆ For the best results, use "selective" pesticides, applied directly on the target, or applied at times when nontarget exposure will be minimized.

- ◆ Occasionally, nontarget plants may be damaged despite all normal precautions during pesticide applications. However, in most cases, damage results from the misuse of pesticides or by accidental exposures.

- ◆ Routes of exposures to nontarget plants include drift, run-off, or overdosage.

**b. Air Pollutants.** Forests and wood plants are affected adversely by air pollution.

- ◆ With the growth of industries came air pollution. Industries such as smelters and brick works released pollution into the air. At the same time, the buildings themselves reduced the amount of vegetation.
- ◆ The more industries that come into being, the greater quantity and variety of air pollutants.
- ◆ Today, industries release huge amounts of pollutants into the air.
- ◆ In descending order, oxidants, sulfur dioxide, and fluorides do the greatest direct damage.
  - Oxidants (ozone, oxides of nitrogen, and peroxyacyl nitrates).
  - Sulfur dioxide.
  - Fluorides (hydrogen fluoride and silicon tetrafluoride).

**c. Salt.** Salt in sufficiently high concentrations is toxic to most ornamental plants. It has its greatest impact in contaminated soils.

- ◆ Soils may have natural concentrations of salt, or become contaminated through human activities.
- ◆ In areas where salt concentrations are naturally high, native plants develop "salt tolerance."
- ◆ Human salt activities that can result in soil contamination include irrigation and

the use of salt to melt snow and ice in northern climates.

- ◆ If concentrations are not too high, it may be possible to wash salt out of the soil with large amounts of uncontaminated water.

## 9-12. CLIMATIC DAMAGE

**a. Drought, Excess Water, and Freezing.** Ornamental plants that are not adapted to local climatic conditions are susceptible to injury and death when conditions are unfavorable.

(1) Drought. Plants vary in their ability to withstand low water potential.

- ◆ Generally, drought is the greatest risk to seedlings and recently transplanted plants which can quickly die if they do not receive large quantities of water while roots become established.
- ◆ Drought-stressed plants are also especially vulnerable to attack by insects and infectious diseases, as well as winter injury in cold climates.
- ◆ Symptoms of drought stress include:
  - Reduced turgor.
  - Droop.
  - Wilt.
  - Yellowing and browning of leaves.
  - Leaf drop.
- ◆ The best way to prevent drought damage is to select ornamental varieties adapted to "worst case" conditions for the area where they are to be planted.

(2) Excess water. Flooded or waterlogged soils kill plants by depriving roots of oxygen (anoxia). Some ornamental plants will not survive more than a few days of flooding. Damage may be the result of natural flooding. It can also result from excess watering, especially of newly planted ornamentals in poorly drained, clay soils.

(3) **Freezing.** Freezing temperatures may cause wilt and leaf drop of susceptible plants. This may or may not cause serious injury to the plant. Freezing of the soil may immediately kill unadapted plants. Freeze damage also interferes with plant defenses against opportunistic fungi and other pathogens.

b. **Lightning.** The greatest impact of lightning is as a cause of forest fires. However, it can cause significant damage to forest trees and ornamentals in the absence of fire. The damage may be largely cosmetic. However, the injury caused by lightning can also significantly reduce plant defenses against attack by insects and pathogens. Wounds caused by lightning are particularly susceptible to invasion by wood boring insects and attack by pathogenic fungi.

## Section V. DISEASE SAMPLING PROCEDURES

### 9-13. THE CONTACT

Contact your local agricultural extension service to determine the preferred methods of collecting and shipping plant specimens for analysis.

### 9-14. THE SAMPLES

Begin by taking samples from the margins of infected areas. Partially infected leaf blades often make the best samples.

- ◆ Snip infected foliage, not foliage that is completely dead or decayed.
- ◆ Wrap sample in aluminum foil.
- ◆ Take separate samples of infected leaves or stems and adjacent healthy samples.
- ◆ Give a complete history of the diseased area.

## EXERCISES, LESSON 9

**REQUIREMENT.** The following exercises are to be answered by completing the incomplete statement or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

1. The three conditions necessary for plant disease to occur are:

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

2. List the five causal agents of plant diseases.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

3. Five environmental conditions that may cause plant damage are:

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

4. Leafspots, blights, vascular wilts, soft-rots, galls, and tumors are \_\_\_\_\_ diseases which damage plants.

5. Three types of plant damage caused by fungi are:

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

6. Fill in the blank with either the word "bacteria" or the word "fungus."

a. Leafspots appearing as stripes are caused by \_\_\_\_\_.

b. Leafspots appearing as localized lesions and resulting from dead and collapsed cells are caused by \_\_\_\_\_.

7. How do nematodes injure plants? \_\_\_\_\_

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8. List three ways virus and viroid diseases can be spread.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

9. Parasitic plants damage trees by \_\_\_\_\_

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10. Wounds caused to trees by lightning result in trees being very susceptible to what two problems?

a. \_\_\_\_\_

---

b. \_\_\_\_\_

---

**END OF LESSON EXERCISES**



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## LESSON ASSIGNMENT

### LESSON 10

-- Forest Management.

### LESSON ASSIGNMENT

-- Paragraphs 10-1 through 10-19.

### TERMINAL LEARNING OBJECTIVE

-- Information gained in this lesson should enable you to employ integrated pest management principles IAW U.S. Forest Service Agriculture Handbook No. 608 to identify and control economic pests of forests.

### SPECIFIC LESSON OBJECTIVES

-- After completing this lesson, you should be able to:

10-1. Identify the goal of forest pest management.

10-2. Identify the method(s) best suited for forest pest management.

10-3. Identify forest damage caused by the following forest weeds:

- ◆ Weed trees.
- ◆ Herbaceous plants.
- ◆ Vines.

10-4. Identify forest damage caused by the following forest pests:

- ◆ Defoliators.
- ◆ Juice feeders.
- ◆ Bark beetles.
- ◆ Wood borers.
- ◆ Shootborers.

10-5. Identify the advantages and disadvantages of the following forest pest control methods:

- ◆ Cultural controls.
- ◆ Biological controls.

### SUGGESTION

-- After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 10

### FOREST MANAGEMENT

#### Section I. FOREST PEST/ INTERACTIONS

##### 10-1. INTRODUCTION

Forestry is big business for the Department of Defense. The DoD manages millions of acres of commercial forest land throughout the continental United States. Forestry programs generate funds by selling forest products such as pulpwood and timber, and using these funds to defray program costs. In effect, the forestry program is self-sustaining and requires little input of taxpayer dollars. Foresters deal with a huge variety of biological and commercial issues, and plan their program 30 to 100 years ahead. So pest management is only one of many components of a successful forestry program, and yet, it is a crucial part of the program.

##### 10-2. GENERAL INFORMATION

a. **Forest Pest Damage.** Forest pests are best considered as agents of forest disturbance, similar to fire or windstorms. A pest outbreak acts as a thinning agent. The number of trees in a stand is decreased. Since the remaining trees are freed from competition for soil nutrients, water, and sunlight, the trees are able to grow rapidly for a number of years, and pest problems are minimized during this period of rapid growth.



Figure 10-1. Forest.

b. **Tree Competition.** Competition between individual trees and the death of older and less-competitive trees is a fact of forest ecology. As a tree stand ages, the leaf canopy becomes complete so that all possible locations for light reception are occupied by leaves. The soil is fully occupied by tree roots. In this situation, growth slows to a minimum. The weakened trees are easy victims of forest diseases or insects. Even without a pest outbreak, fire, or windstorm, trees will die from the effects of competition, usually at the rate of one or two percent per year.

c. **Goal of Forest Pest Management.** The goal of forest pest management is not to destroy all insects, diseases, or other pests which feed on trees. These living things are part of the forest ecosystem. The foresters' goal is to maintain stands of rapidly growing trees with sufficient resources to endure feeding by insects, fungi, and other organisms. The forester takes heroic pest control measures only to protect the forest from intense, catastrophic pest damage.

##### 10-3. FREQUENCY vs. INTENSITY

Forests are well adapted to frequent, low-intensity disturbance. For example, North American forests evolved under a regime of frequent, low-intensity fires. This type of disturbance does not damage the forest ecosystem or cause long term effects. On the other hand, infrequent, high-intensity disturbances, such as a gypsy moth outbreak, can alter the entire forest ecosystem. The forester uses all available pest management techniques to avoid these high-intensity disturbances.

## Section II. SPECIALIZED FORESTRY SETTINGS

### 10-4. GENERAL INFORMATION

Although commercial forests are not damaged by low-intensity pest infestations, there are specific forestry situations in which the tolerable threshold for pest damage is much lower.

### 10-5. SPECIALIZED, HIGH RISK FORESTRY PROGRAMS

Forestry programs which will **NOT** tolerate the normal, low-intensity pest pressure include:

- ◆ Tree nurseries.
- ◆ Seed orchards and seed.
- ◆ Production areas.
- ◆ Christmas tree plantations.
- ◆ Turpentine plantations.
- ◆ Arboretums, research plots, or wind breaks.
- ◆ Urban or suburban forests.

In each of these situations, tree value is much higher than in a normal forest, and even low level pest damage is unacceptable.

## Section III. FOREST PESTS: WEEDS

### 10-6. GROUPED BY PLANT TYPE

Forest pests may be broadly grouped into herbaceous plants, weed trees, and vines.

**a. Weed Trees.** Weed trees are the most serious pest plants found in forestry situations. The forester plants trees which are adapted to the soil and climatic conditions of the area and which have some commercial value; other competing trees become weeds. Common weed trees are red maple, persimmon, wild cherry, and other hardwoods which grow in stands of conifers.

**b. Herbaceous Plants.** Herbaceous plants (plants with the characteristics of herbs) do not produce persistent woody tissue. These plants do not persist in forest ecosystems, but may pose a problem in newly planted areas where the weeds shade out young seedling trees. Knapweed and leafy spurge are examples of herbaceous plants.

**c. Vines.** Vines, such as poison ivy and kudzu, pose a special control problem to the forester. These plants use trees for support, and this growth habit makes control very difficult. Because the vine is wrapped around the tree, any chemical control will inevitably come into contact with the trees. Mechanical control is also difficult because the vines are in such close proximity to the trees.

### 10-7. WEED CONTROL METHODS

**a. Mechanical Controls.** These controls include power tools which mow, disk, chop, rip, or otherwise destroy unwanted vegetation. Most of these tools are pulled by crawler tractors or rubber tired skidders. The tools usually tear weed roots out of the ground or slice off weed stems. The main disadvantage of mechanical controls is soil disturbance. The tools may damage soil through erosion, compaction, or nutrient loss.

**b. Prescribed Fire.** Prescribed fire is simply the planned use of fire. Usually, the forester uses fire to reduce hazardous levels of fuel, prepare sites for seeding or planting, control insects and diseases, maintain fire-dependent species and ecosystems, or manage wildlife habitat. This technique is inexpensive. The forester can treat thousands of acres within a relatively short time with small inputs of labor. Disadvantages include the risk of wildfire and the possibility of damaging valuable trees.

**c. Manual Removal.** Weeds are removed with hand-operated power tools or non-powered tools. The tools are used to sever plant stems above the ground with no soil disturbance. This technique is used on all kinds of terrain and causes no damage to forest soils. Disadvantages include the safety risk of handling sharp tools, and the problem of resprouting from cut stumps.

WEED CONTROL METHODS + DISADVANTAGES	
THE METHOD	THE DISADVANTAGES
Mechanical Controls	<ul style="list-style-type: none"> <li>♦ Soil disturbance: erosion compaction nutrient loss</li> </ul>
Prescribed Fire	<ul style="list-style-type: none"> <li>♦ Risk of wildfire.</li> <li>♦ Possibility of damaging valuable trees through wildfire.</li> </ul>
Manual Removal	<ul style="list-style-type: none"> <li>♦ Safety risk when handling sharp tools.</li> <li>♦ Problem with resprouting from cut stumps.</li> </ul>
Insects and Diseases	<ul style="list-style-type: none"> <li>♦ No real disadvantages, but the technique is slow.</li> <li>♦ Technique takes a lot of money for research certification.</li> </ul>
Grazing.	<ul style="list-style-type: none"> <li>♦ Must tend the animals.</li> <li>♦ Possible damage to beneficial plants.</li> </ul>
Herbicides	<ul style="list-style-type: none"> <li>♦ Risk to human health.</li> <li>♦ Possible environmental damage.</li> </ul>

**d. Insects and Diseases.** Beneficial insects and plant diseases have been used against herbaceous weeds like spotted knapweed and leafy spurge. This technique has no real disadvantages, but is slow and takes an enormous investment in research and certification.

**e. Grazing.** Cattle and other grazing animals may be used to control herbaceous weeds and some small woody species. Disadvantages include the need to tend the animals, and the possible damage to beneficial plants.

**f. Herbicides.** The forester uses herbicides to control woody and herbaceous plants. The chemicals are applied by backpack sprayers, spotguns, injectors or hypo-hatchets (for weed trees), boom sprayers, and granular spreaders. Herbicides are cheaper than other control methods and usually control resprouting. Disadvantages include the risk to human health and possible environmental damage.

#### Section IV. FOREST PESTS: INSECTS

##### 10-8. GROUPED BY FEEDING DAMAGE

**a. Defoliators.** Insects which feed on leaves are collectively called defoliators.



Examples of defoliators include gypsy moth, Eastern tent caterpillars, fall webworms, and bagworms. Trees can endure a great deal of foliage loss. A healthy tree can lose 40 percent of its foliage every year with no effect. The loss of more than 40 percent of foliage may damage or kill a tree. Gypsy moths and bagworms may remove all of a tree's foliage, causing severe damage or death.

**b. Juice Feeders.** Insects which suck out plant juices may cause severe tree damage. Aphids, scales, and adelgids cause tree damage by removing plant nutrients and injecting toxic salivary materials. These insects may also transmit viral diseases.



c. **Bark Beetles.** Bark beetles bore into the tree bark, and feed in the cambium layer just below the outer bark. When the cambium layer is severed, the tree dies. The most notorious of these insects is the Southern pine bark beetle, one of more than 200 bark beetles found in the United States. The Southern pine bark beetle feeds on Southern pine species and occurs in huge numbers. The infestation usually begins in a weakened tree and spreads to healthy trees when insect numbers increase. Other bark beetles cause similar damage.

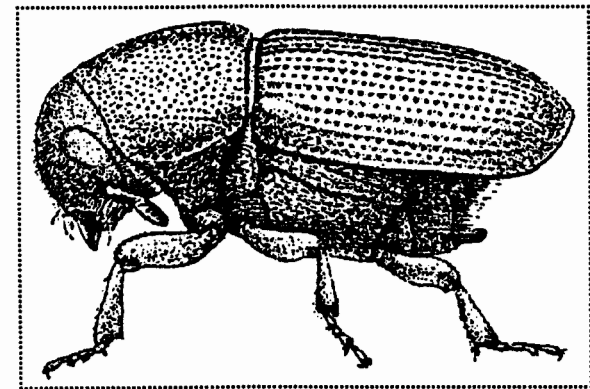


Figure 10-2. European elm bark beetle.

d. **Wood Borers.** These insects (moth or beetle larva) live inside woody stem tissue. The adult usually lays eggs in cracks in the outer bark. The larvae then bore into the stem and pupate within the wood.

- ◆ Damage results from introduction of decay fungus or mechanical weakening of the stem.

e. **Shootborers.** Shootborers (moth or beetle larvae) enter young branches and feed in the center or pith of the shoot. The insects destroy the xylem tissue of the shoot, and the branch dies. Insect feeding may also weaken the shoot, which breaks off later. One interesting beetle species, the twig girdler, lays eggs on the outer branch, then chews off the branch so the eggs may hatch on the ground. The larvae then bore into the fallen branch and begin development.



### **FOREST PEST INSECTS GROUPED BY FEEDING DAMAGE**

- »» Defoliators.
- »» Juice feeders.
- »» Wood borers.
- »» Shootborers.

### **10-9. CULTURAL/ BIOLOGICAL CONTROLS OF FOREST INSECTS**

a. **Cultural Controls.** Insect pests of forest trees can sometimes be controlled by silvicultural methods (silviculture = development and care of forests). The forester tries to create a diverse and healthy forest system, rather than an even-aged monoculture which may be susceptible to insect infestation. Cultural controls include:

- ◆ Planting trees in mixed stands of hardwoods and conifers.
- ◆ Creating mixed-age stands where the natural forest species occurs in pure stands (for example; ponderosa pine, jack pine, and red pine).
- ◆ Thinning to stimulate rapid growth.
- ◆ Planting improved varieties and adapted species.
- ◆ Removing high-risk trees and prompt salvage of infested trees.
- ◆ Disposing of logging residues.

**NOTE: Cultural methods such as pruning, which are effective on ornamental trees, are too expensive for forestry.**

b. **Biological Controls.** Biological controls usually involve the introduction of insect parasites and predators.

(1) **Parasites.** Generally, forest entomologists have concentrated on parasites. Parasitic insects are usually hymenoptera or diptera. These insects have slender ovipositors

which they use to insert eggs into the host. The eggs hatch within the host's body, and the larvae feed on the host. Some parasites glue eggs to the host's body. The larvae then burrow into the host. Other parasites deposit eggs in the host's cocoon. The eggs hatch quickly, and the larvae feed inside the cocoon.

(2) Predatory insects. Predatory insects include ladybird beetles, lacewing flies, checkered beetles, ground beetles, and hemipterans such as assassin bugs.

(3) Disadvantages of biological controls. Biological control is usually slow and seldom results in the destruction of the pest species. Great care is required to avoid releasing a damaging or undesirable species.

## 10-10. CHEMICAL INSECTICIDES

Forests are so large and extensive, and insecticides are so expensive, that chemicals are seldom used to control outbreaks of forest insects. Only devastating outbreaks of defoliating insects are routinely controlled using insecticides. One insecticide used successfully to control forest insects is *Bacillus thuringensis*, which is effective against moth larvae. This insecticide is applied from aerial sprayers.

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## Section V. FOREST PESTS: DISEASES AND NEMATODES

## 10-11. FUNGUS DISEASE

Trees are susceptible to a variety of fungal diseases including leaf spots, root rots, galls, tumors, wilts, rusts, and trunk decay. See lesson 8 for a detailed discussion of fungus biology.

## 10-12. CULTURAL CONTROLS OF FUNGAL DISEASES

a. **Plants and the Site.** Fungus diseases thrive on weakened, slowly growing trees. Planting trees adapted to the site goes a

long way to reduce fungus damage because healthy trees can usually throw off the disease. For example, annosus root rot is more severe in deep, well-drained sandy soils; littleleaf disease of shortleaf pine is directly related to low fertility and poor drainage.

b. **Resistant Seeds/Seedlings.** Plant breeding has produced superior tree varieties with (sometimes) increased disease resistance. The use of resistant varieties, when available, can reduce disease damage.

c. **Spacing, Thinning, Clearcutting.** Fungus diseases can be limited, in many cases, by selective tree removal and proper tree spacing. Trees grow quickly when given sufficient space to satisfy requirements for light, moisture, and soil nutrients. Rapidly growing trees are very resistant to disease. For example, wide spacing helps prevent annosus root rot. Oddly, close spacing tends to restrict the development of fusiform rust, because the closely spaced pines restrict growth of oaks, which are the alternate host for the rust. A severely infected stand may be removed by clearcutting, thus arresting the disease.

d. **Fungicides and Nematicides.** Fungicides are not used in forest situations because of prohibitive cost. In fact, most fungicides don't kill fungus, but arrest fungal development, so the treatment is not effective long-term.

- ◆ Soil fumigants and fungicide sprays are used in tree nurseries, where disease may cause heavy losses.
- ◆ Soil fumigation controls root and soil diseases.
- ◆ The fumigants are nonselective and also control soil insects.
- ◆ Fungicide sprays control stem, branch, and foliage diseases.

## Section VI. FOREST PESTS: PARASITIC PLANTS

### 10-13. PARASITIC PLANTS

Trees are susceptible to attack by mistletoes and dwarf mistletoe, flowering plants which live on and obtain nutrients from growing trees. Parasitic plants produce seeds which may be eaten by birds (true mistletoes) and be deposited on tree branches, or may be propelled out of seed pods (dwarf mistletoe) and shoot through the air onto nearby branches. The seeds germinate and seedling roots invade the branch.

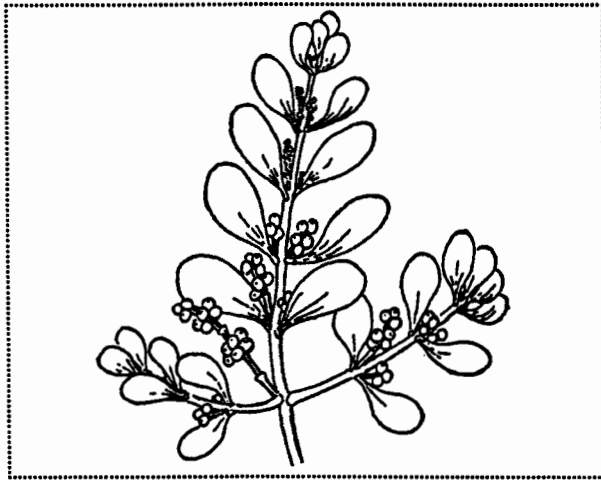


Figure 10-3. Mistletoe.

### 10-14. DAMAGE

The most common damage from parasitic plants is reduced tree growth. Most trees show stem deformities, such as swellings or witches' brooms. Some trees die back, particularly after infestation by dwarf mistletoe.

### 10-15. CONTROL

Parasitic plants can be controlled by pruning, but this is impractical in forestry. The most practical controls are proper species selection (because species vary in susceptibility to parasitic plants) and removal of infected trees.

## Section VII. FOREST PESTS: VERTEBRATES

### 10-16. VERTEBRATE ANIMALS

Trees provide food and nesting material for a variety of vertebrate animals. Vertebrate animals usually cause slight damage. Seedling trees, however, may be destroyed by animal feeding, and flooding caused by beaver may destroy large areas of mature timber.

### 10-17. DAMAGE

#### a. Clipping and Browsing Seedlings.

A variety of herbivorous animals may clip and browse on trees. Although this feeding is usually not damaging to mature trees, seedlings may be killed outright. Browsing and clipping animals include rabbits, pocket gophers, deer, and elk.

#### b. Flooding.

Beavers dam up flowing waters to create their own wetland habitat. These ingenious animals not only feed on tree bark, they fell trees to make their dams. Flooding is caused by the dammed up stream, and many acres of forest may be killed.

#### c. Seed Feeding.

Squirrels, field mice, and other rodents feed on tree seeds. Natural regeneration may be severely restricted by rodent feeding. Planted seeds may be excavated and eaten by rodents.

### 10-18. CONTROLS

Vertebrate species may be controlled by a variety of methods, but the control must be evaluated for efficacy and cost-effectiveness. Some controls to be evaluated are:

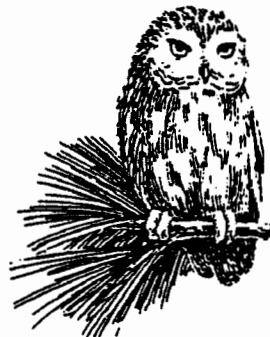
- ◆ Fences.
- ◆ Sound and light devices (to frighten away browsing animals).
- ◆ Barriers to protect individual trees from feeding.
- ◆ Recreational hunting to control deer, elk, rabbits, and other animals.



- ◆ Seedling protectors to discourage clipping by rabbits or deer.
- ◆ Habitat manipulation to remove food sources for various species.
- ◆ Chemical treatments such as repellents (putrescent egg solids, capsaicin, and thiram) to discourage deer and other browsers.
- ◆ Baits and fumigants are used to control seed-feeding rodents.
- ◆ Trapping and hunting to control large beaver populations.

#### 10-19. CLOSING

Forestry pest control is extremely complex and requires a deep understanding of biological principles and the techniques of survey, monitoring, and control. Forestry pest control is less chemical-dependent than any



other area of pest control. In most cases, the forester uses silvicultural techniques, such as species selection, spacing, age management, thinning, selective removal, or removal of diseased/infested trees to

achieve control. Chemicals are used only to avert a disaster, such as forest destruction from a pest like the gypsy moth. In many situations, chemicals are ineffective even if cost and environmental damage were discounted. The Southern pine and other pine beetles cause widespread damage, but effective chemical controls aren't available. The forester must plan treatments carefully to achieve effective, but safe and environmentally sound pest management.

## EXERCISES, LESSON 10

**REQUIREMENT.** The following exercises are to be answered by completing the incomplete statement or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

1. What is the goal of forest pest management? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

2. How do forest pests act as thinning agents? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

3. Some forestry programs won't tolerate the low-intensity, normal pressure of pests. List four such programs.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_

4. List two problems with using insects and diseases to control herbaceous weeds such as the spotted knapweed and the leafy spurge.

- a. \_\_\_\_\_
- b. \_\_\_\_\_

5. List two disadvantages to using herbicides to control woody and herbaceous plants in the forest.

- a. \_\_\_\_\_
- b. \_\_\_\_\_

6. How do aphids, scales, and adelgids--juice feeders--cause tree damage? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

7. List three cultural controls of forest insects.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

8. Squirrels, field mice, and other rodents restrict regeneration of trees by \_\_\_\_\_  
\_\_\_\_\_

9. List two reasons insecticides are seldom used to control outbreaks of forest pests.

- a. \_\_\_\_\_  
\_\_\_\_\_
- b. \_\_\_\_\_  
\_\_\_\_\_

10. List five methods to control vertebrates--  
deer, beavers, elk, etc.--in forests.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

**END OF LESSON EXERCISES**



## LESSON ASSIGNMENT

<b>LESSON 11</b>	-- Identification and Management of Turf Diseases.
<b>LESSON ASSIGNMENT</b>	-- Paragraphs 11-1 through 11-29.
<b>TERMINAL LEARNING OBJECTIVE</b>	-- Information gained in this lesson should enable you to utilize the principles of integrated pest management to manage diseases of turfgrass.
<b>SPECIFIC LESSON OBJECTIVES</b>	-- After completing this lesson, you should be able to:  11-1. Identify the causal agents of turfgrass diseases.  11-2. Identify the symptoms of turfgrass diseases.  11-3. Identify the pest management technique used to control turfgrass diseases.  11-4. Calculate the pesticide dosage for a specific turfgrass disease.
<b>SUGGESTION</b>	-- After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 11

### IDENTIFICATION AND MANAGEMENT OF TURF DISEASES

#### Section I. INTRODUCTION

#### 11-1. HISTORICAL PERSPECTIVE

For nearly 2,000 years, turfgrasses have been recognized for their importance to the quality of life. Turfgrasses graced the landscape in the palace gardens of the emperor during the Han Dynasty in China around the time of 100 B.C. In today's world, turfgrasses are both useful and ornamental. Ornamentally, turfgrasses beautify the landscape and provide the cover for sports' playing fields. Functionally, turfgrasses reduce noise and air pollution (turf around airfields reduces noise and dust), heat

buildup, visual pollution, and glare when maintained around homes, businesses, parks, public institutions, and other facilities.

#### 11-2. GENERAL INFORMATION

Intensively managed turfgrass is extremely susceptible to a variety of disease organisms. Management of turfgrass diseases requires the ability to identify causal organisms by observing symptoms, and detailed knowledge of cultural and chemical controls.

- ◆ In this lesson, we will discuss some of the more important turfgrass diseases and many of the available preventive and curative control measures.

## LESSON ASSIGNMENT

<b>LESSON 11</b>	-- Identification and Management of Turf Diseases.
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## LESSON 11

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## Section II. INFECTIOUS DISEASES: FUNGI

### 11-3. GENERAL INFORMATION

#### a. Turfgrass and the Environment.

Plants are very responsive to extremes in their environments. To maintain health, plants must adapt completely to the region in which they are growing. Turfgrass, along with other plants, is susceptible to a number of environmental problems, one of which is fungal disease.

#### b. General Information About Fungi.

Fungi are microscopic organisms lacking chlorophyll. These organisms are multicellular and usually filamentous. They have well-developed cell walls and reproductive systems and are generally reproduced by spores (one to many-celled reproductive bodies). Spores may be formed asexually or as the result of a sexual process. A large group of fungi, the Fungi Imperfecti, reproduce only asexually. Fungi vary in size from as small as bacteria (visible only by microscope) to as large as mushrooms (clearly visible without a microscope). Insects, animals, and machinery can carry fungi over long distances. Fungi cause most recognized turfgrass diseases.

**c. Fungal Anatomy.** Most fungi have a plant-like body which consists of elongated, continuous, branched, microscopic filaments. These filaments have definite cell walls. The fungus body is called a mycelium, and the individual filaments are called hyphae. Hyphae range in thickness from 0.5 micrometers to more than 100 micrometers. The mycelium may be a few micrometers or several meters long.

**d. Fungus Ecology.** Most pathogenic fungi spend part of their life cycle on the host plant; they spend another part of their life in the soil or on decaying plants in the soil. A few fungi spend their entire life on the host plant. The spores remain inactive on the soil, until brought into contact with the living host. Other fungi live as parasites on the host plant, then continue to live as saprophytes on the decaying host plant tissue. Many plant pathogens survive for years as saprophytes, but must infect a living plant to achieve population increase.

**e. Infection Characteristics.** Parasitic fungi vary as to the plant cells or tissues colonized. Fungi such as powdery mildew are surface dwellers. The fungi grow on the leaf surface, but send feeding organs (haustoria) into the epidermal cells. Some fungi grow between the leaf cuticle and the epidermal cells. Some fungi grow in intercellular spaces, while others grow through and between cells. Obligate parasites (which must live as parasites) can only grow in living host cells, but some nonobligate parasites produce enzymes which kill plant cells ahead of the mycelium. Almost all fungi produce spores on the host plant surface, regardless of the part of the plant colonized.

### **INFECTIOUS DISEASES CAUSED BY FUNGI**

- ◆ Rhizoctonia brown patch
- ◆ Sclerotinia dollar spot
- ◆ Pythium diseases
- ◆ Copper spot  
(Zonate leaf spot)
- ◆ Red-thread effects
- ◆ Fusarium diseases
- ◆ Pink snow mold  
(Fusarium patch)
- ◆ Typhula blight  
(Gray snow mold)
- ◆ Helminthosporium diseases
- ◆ Rusts
- ◆ Powdery mildew
- ◆ Leaf smuts
- ◆ Take-all patch

### 11-4. RHIZOCTONIA BROWN PATCH

**a. Symptoms.** Symptoms vary depending on the turf species as well as the soil condition, atmospheric environment, and species of rhizoctonia.

- ◆ Foliar blight and root rot are characteristic of the disease.
- ◆ Pathogen growth begins at 65°F and is most active when the temperature is warm (80° to 85°F) and humid.

Brown patch is considered to be one of the most destructive of all turf diseases.

**b. Sclerotia and the "Smoke Ring" or "Halo" Phenomenon.** The pathogen overwinters as "sclerotia" in plant tissue. Sclerotia is a mass of hyphae, usually with a darkened rind, capable of withstanding difficult weather conditions. The disease shows up as a large patch of blighted and dying grass. Individual patches may be three to five feet in diameter. Often, especially during warm, humid weather, the patches may be surrounded by a grayish-brown or purplish border called a "smoke ring" or "halo." As the fungus infects grass tissue at the edge of the patch, all the affected grass blades wilt at the same time, causing the smoke ring phenomenon. The smoke ring is usually seen in the early morning when the grass is covered with dew or during very humid weather. Sometimes the smoke ring does not occur.

**c. Control.**

- ◆ Avoid excessive nitrogen.
- ◆ Irrigate seldom and deeply.
- ◆ Use labelled fungicides as necessary.

**11-5. SCLEROTINIA DOLLAR SPOT**

**a. Information.** Dollar spot affects bermudagrass, St. Augustine grass, zoysiagrass, centipedegrass, and bahiagrass. There are no resistant varieties. Dollar spot is a common and persistent disease, but only on turf with low nitrogen levels.

**b. Symptoms.** Small, circular, sunken patches on closely mowed turf are symptoms of this disease with the patch usually not more than six centimeters in diameter.

- ◆ Turfgrass leaves develop yellowish or tan lesions with dark brown borders.
- ◆ Fungal mycelium is visible in early morning before the dew dries.
- ◆ Individual lesions are often hourglass-shaped.

**c. Conditions for Development/Dissemination.** This disease thrives in warm, humid weather with cool nights and heavy dew.

The problem is more severe when the soil is dry and nitrogen levels are low. Sclerotinia dollar spots overwinter as dormant mycelium in plant crowns and roots. The disease is spread by equipment and foot traffic.

**d. Control.**

- ◆ Maintain nitrogen fertility.
- ◆ Irrigate seldom and deeply.
- ◆ Contact fungicides are effective.

**11-6. PYTHIUM DISEASES**

**a. Information.** Pythium is a devastating foliar blight, crown, and root rot affecting most turfgrasses. There are no resistant varieties.

**b. Symptoms.** Symptoms are always associated with wet conditions.

- ◆ The turf quality declines rapidly with yellowing and thinning.
- ◆ Roots are thin and have very few root hairs. Leaves may have small water-soaked patches, fading to a light brown with "halo."
- ◆ Whitish mycelium may cover infected leaves. The mycelium is visible in early morning.

**c. Conditions for Development/Dissemination.** Pythium is favored by hot, humid weather. An old rule predicts pythium will occur when nighttime temperature in degrees Fahrenheit plus relative humidity equals 150. This rule predicts pythium too frequently. More accurate models, also based on temperature and humidity, have been developed. Pythium is spread in free water or carried on equipment, shoes, etc.

**d. Control.** Because pythium is so closely associated with free water, water control is the key to managing this disease.

- ◆ Improve soil drainage, if necessary.
- ◆ Aerate to improve water infiltration.
- ◆ Irrigate as little as possible.

- ◆ Raise mowing height.
- ◆ Use fans to dry up dew and reduce humidity on golf greens.
- ◆ Irrigate fungicides into the root zone (when using fungicides) as a curative.
- ◆ Golf course managers—apply fungicides as a preventive during summer when conditions are favorable for disease development.

#### 11-7. COPPER SPOT (ZONATE LEAF SPOT)

**a. Information.** Copper spot is a foliar disease which is especially damaging to bent grasses.

**b. Symptoms.** Symptoms include scattered, circular patches two to seven centimeters in diameter.

- ◆ The turf color ranges from salmon to copper.
- ◆ Individual turfgrass leaves have light brown or gray lesions with narrow, purplish-brown margins.
- ◆ The margin may fade to brown or turn black.
- ◆ The tissue around the lesion yellows, and severely infected leaves may die.

**c. Conditions for Development/Dissemination.** This disease thrives in warm, wet weather with a temperature of 68° to 75°F.

- ◆ Excess nitrogen and acidic soils promote Copper spot.
- ◆ The fungi are spread by splashing water, equipment, and shoes.

#### **d. Control.**

- ◆ Correct acidic soils with lime applications
- ◆ Avoid heavy applications of nitrogen during warm, wet weather.

- ◆ Use fungicides with labels specifying use for this disease.

#### 11-8. RED-THREAD EFFECTS

**a. Information.** Red-thread is a foliar disease affecting cool-season grasses.

**b. Symptoms.** Symptoms of this disease include irregular patches of water-soaked grass, fading to light brown. The grass has a general, ragged appearance.

- ◆ Pink-to-red or orange fungal growth appears in circular or irregularly-shaped, small-to-large patches of infected grass.
- ◆ Red-thread thrives in humid conditions. Conditions which favor red-thread include fog, light rain, heavy dew, and low soil fertility.

**c. Conditions for Development/Dissemination.** This disease is spread by running water, equipment, shoes, and wind. Red-thread is strongly associated with low fertility.

**d. Control.** Applying nitrogen fertilizer will usually control the fungus.

#### 11-9. FUSARIUM DISEASES

**a. Information.** Different species of fusarium can cause a variety of turfgrass problems: leaf spots; foliar blights; rotting of roots, crowns, stolons, and rhizomes; and diseases in seedlings.

**b. Cool-Season Diseases.** Fusarium diseases occurring during fall and winter months cause patches of foliar-blighted or dead plants under cover of snow or heavy mulch. Leaf blight can occur during cool weather even if snow or heavy mulch is not present.

**c. Leaf Spot and Seedling Diseases.** Fusarium fungi may cause leaf spotting over large turfgrass areas during warm, humid weather. The irregular leaf spots mostly occur on older leaves. Infected spots are tan with brown to purplish-brown margins. Fusarium infections often start at the ends of leaves, resulting in a tip blight.

d. **Crown and Root Rot.** During hot, dry weather, small patches of infected plants turn light green, then quickly fade to tan and straw color.

- ◆ Patches appear in circular or irregular patterns ranging from 2 to 30 cm in diameter.
- ◆ By the time foliar damage is apparent, most of the plants within the infected area have extensive black (or dark brown) rot of crowns, roots, rhizomes, and stolons.
- ◆ White to pink mycelium and spore masses may occur on lower stems and crowns during warm, moist conditions.
- ◆ Leaf lesions may or may not occur.

e. **Conditions for Development/Dissemination.** Conditions which promote these diseases include high temperature, drought, excess nitrogen, thatch, and low mowing. Fusarium diseases are spread mostly by wind.

f. **Control.**

- ◆ Avoid excessive applications of nitrogen.
- ◆ Reduce thatch accumulations.
- ◆ Raise mowing height, if possible.
- ◆ Use fungicides labeled for use on fusarium diseases.

#### 11-10. PINK SNOW MOLD/FUSARIUM PATCH

a. **Information.** The names pink snow mold and fusarium patch, phases of another disease, do not accurately describe the problems for several reasons. The turf looks pink only under some conditions. And, the disease does not occur only to snow-covered turf.

**NOTE:** The name of the pathogen is no longer fusarium but microdochium.

**NOTE:** The name "Pink Snow Mold" is used when referring to a disease associated with melting snow. "Fusarium Patch" was used to describe the same disease occurring without snow cover.

These diseases may occur year round in many cool and humid regions. All cool season grasses are susceptible.

b. **Symptoms.** Circular patches of water-soaked turf appear.

- ◆ The infected turf changes rapidly from green to orange-brown to dark brown to light gray.
- ◆ The infection may expand indefinitely if untreated.
- ◆ Ring-shaped patches may appear on closely mowed turf. The outer edge of the patch may have a greenish-black, water-soaked appearance.
- ◆ A white mycelium may be visible in very wet conditions or under a snow cover.
- ◆ The pink color results when mycelium is exposed to sunlight. Spores are produced in a pinkish matrix of mycelium and sporodochia (asexual fruiting bodies).

c. **Condition for Development/Dissemination.** These diseases survive unfavorable periods in infected plants and dead debris. The diseases are spread by equipment, animals, and shoes. Conditions which favor these diseases include heavy thatch; cool, wet weather (not limited to snow); high nitrogen; low potassium; and poor drainage.

d. **Control.** Control of these diseases is achieved by several methods.

- ◆ Balanced fertilization.
- ◆ Thatch control.
- ◆ Drainage improvement.

#### 11-11. TYPHULA BLIGHT (GRAY SNOW MOLD)

**a. Information.** Typhula blight is also called gray snow mold or speckled snow mold. A gray mat of mycelia and sclerotia develops on infected grass leaves under the cover of snow. This disease is very common in areas with significant snowfall.

**b. Symptoms.** The symptoms of typhula blight are circular patches of yellow, straw, or grayish-brown turf, occurring after the snow melts.

- ◆ The leaves may be matted together and are often covered with white-to-gray mycelium.
- ◆ Small, spherical sclerotia (white or amber-to-dark brown) form on infected leaves.
- ◆ The fungus survives as sclerotia during the summer and tends to recur in the same area indefinitely.

**c. Conditions for Development/Dissemination.** Conditions which are favorable for this disease include deep snow, tall grass, and high nitrogen.

##### **d. Control.**

- ◆ Reduce nitrogen levels in late autumn.
- ◆ Keep grass closely mowed.

#### 11-12. HELMINTHOSPORIUM DISEASES

**a. Information.** The helminthosporium diseases are caused by several species of fungi. These fungi are active throughout the year on warm-season turf. The leaf-spot symptoms usually occur during mild spring and fall weather. Root-rot or "melting out" phases usually occur during the summer months.

##### **b. Symptoms.**

- ◆ Leaf lesions are brownish-green to black, many lesions having white centers.
- ◆ Crown and root rots appear in late spring and summer.

- ◆ Large patches of thinning turf are visible.

**c. Conditions for Development/Dissemination.** Helminthosporium diseases attack most turfgrasses. The diseases survive as spores and dormant mycelium in debris or infected tissue, growing saprophytically.

- ◆ Conditions which favor the diseases include moisture and humidity; shade; low mowing; thatch; and high nitrogen in the soil.
- ◆ Helminthosporium diseases are spread by wind, rain (or irrigation), equipment, shoes, and animals.

##### **d. Control.**

- ◆ Reduce thatch accumulation.
- ◆ Balance fertilizer applications.
- ◆ Irrigate infrequently and deeply.
- ◆ Raise mowing height.
- ◆ Several fungicides are effective against.

#### 11-13. RUSTS

**a. Information.** Rust diseases are common on most crop plants, including all turfgrasses. Identification is by the characteristic red-orange pustules found on infected leaves. Grasses are most susceptible to rust fungi when already under stress from low-fertility, drought, and other environmental factors. Turfgrass infected is more susceptible to environmental stresses and attacks by other pathogens.

##### **b. Symptoms.**

- ◆ Light yellow leaf flecks with orange-to-brick red pustules following are early symptoms of rust disease.
- ◆ The plants wither and die.
- ◆ The entire turf becomes tinted red, brown, or orange by pustules and spores.

**c. Conditions for Development/Dissemination.** Rust disease survives as spores or mycelium in infected plants and is spread by the wind. Conditions favorable to rust disease include drought, nutrient deficiency, low mowing height, shade, and leaf wetness.

**d. Control.** Avoid all management practices which may further stress the turf.

- ◆ Apply balanced fertilizers and irrigate deeply.
- ◆ Apply appropriate fungicides. (Be sure the label clearly states that the fungicide is for use on rust diseases.)

#### 11-14. POWDERY MILDEW

**a. Information.** Powdery mildew occurs on susceptible turfgrass which is grown in shaded areas with poor air circulation. Powdery mildew weakens grass plants so that the plants are killed by other stresses.

##### **b. Symptoms.**

- ◆ The disease can be seen on bluegrass and fescue leaves as fine, whitish mycelia which appears powdery or dusty.
- ◆ This disease colonizes the epidermal cells of grass leaves.
- ◆ The mycelia takes nutrients from epidermal cells, and the grass leaves turn yellow.
- ◆ Some leaves and tillers may die, and the turf loses density.

**c. Conditions for Development/Dissemination.** Powdery mildew overwinters as mycelium in living plants. This disease is spread in water or wind. Favorable conditions for powdery mildew to develop include cool, wet weather and shade.

**d. Control.** Powdery mildew is so strongly associated with shade, that reducing shade and increasing air circulation is the primary cultural control. Many times this control method is impractical because the loss of trees or structures would be involved.

- ◆ Use shade-tolerant varieties.
- ◆ Increase mowing height.
- ◆ Use a balanced fertilizer program.
- ◆ Apply labelled fungicides.

#### 11-15. LEAF SMUTS

**a. Information.** The pathogens of smut fungi cause diseases of leaves, sheaths, stems, and flowers. Stripe, flag, and blister smuts are the most common leaf smuts. The most widespread and destructive of the diseases is stripe smut. Stripe smut occurs mostly on Kentucky bluegrass, and sometimes on bentgrass and perennial ryegrass.

**b. Characteristics.** Stripe smut is characterized by narrow, yellow-green streaks parallel to leaf veins.

- ◆ The stripes darken to gray as the disease progresses.
- ◆ The streaks rupture and release black, dusty spores.
- ◆ Leaves split or shred between veins and die.

◆ Symptoms are most common during the cool periods of spring and fall.

◆ Weakened plants may be killed by other stresses or fungi.

**c. Conditions for Development/Dissemination.** The smut fungi overwinters as spores in the soil, thatch, or infected foliage.

- ◆ Conditions favorable to leaf smut include cool temperatures; high nitrogen in the soil; acid soils; excess thatch; and drought stress.
- ◆ Spores are spread in water, wind, or by infected grass clippings.

##### **d. Control.**

- ◆ Use a balanced fertilizer program.
- ◆ Raise the mowing height during summer months.
- ◆ Irrigate deeply at the first sign of drought stress.
- ◆ Use resistant varieties.

- ◆ Apply systemic fungicides labeled for use on leaf smut disease.

#### 11-16. TAKE-ALL PATCH

**a. Information.** Take-all patch is a severe, bentgrass disease occurring mostly in cool and temperate regions. Typically, this disease takes place in poorly drained soil. The turfgrasses most resistant are bluegrass and fescue.

##### **b. Symptoms.**

- ◆ Small dead patches of grass appear in the late spring, then spread throughout the year.
- ◆ The entire grass plant turns brown-to-black and dies.
- ◆ The center of the dead patches is invaded by weeds or resistant grasses like fescues or bluegrasses.

**NOTE:** Symptoms of infection may not be noticeable until after a period of drought stress in the late summer. The stressed grass turns bronze or reddish-brown, then fades to brown.

**c. Conditions for Development/Dissemination.** This disease is usually confined to bent grasses.

- ◆ Take-all patch flourishes primarily in cool temperate regions, often on poorly drained, wet, soils or on soils that have been limed recently.
- ◆ Mycelium survives on living grass and thatch.
- ◆ The disease spreads by root-to-root contact, infected sod, and possibly by equipment movement.
- ◆ Conditions which favor this disease include cool, wet weather; poorly drained soil; high pH; and low fertility.

**d. Control.** This disease is difficult to control.

- ◆ Use acidifying fertilizers to correct high pH conditions.
- ◆ Maintain adequate levels of phosphorus and potassium.
- ◆ Remove affected patches and resod with healthy material.
- ◆ As a preventative in late summer, apply fungicides labeled for use on take-all patch.

### Section III. OTHER AGENTS, DISEASES, DISORDERS

#### 11-17. GENERAL INFORMATION

A number of other problems can affect the health of turfgrass: mycoplasmal diseases; mycorrhizae; endophytic fungi; nematode diseases; and viral diseases. In this section, we are going to examine viral diseases and nematode diseases.

#### 11-18. VIRAL DISEASES

**a. Information.** Viruses, possibly causing mild, minor infections of turf, often go unnoticed and/or unreported. These submicroscopic agents require a living host cell to multiply. They are spread by insects, nematode vectors, or mechanical transmission of infected sap (through mowing or cultivation).

**b. St. Augustine Decline.** One example of a virus which attacks turfgrass is St. Augustine decline. This complex virus disease causes chlorotic mottle or mosaic on leaf blades. Affected turf becomes uniformly chlorotic, and stolon growth is retarded.

- ◆ This disease may kill entire lawns as early as three years after the appearance of the first symptoms. The disease is mostly spread by mechanical transmission of plant sap.

c. **Control.** Resistant varieties are the only control for St. Augustine decline.

- ◆ The University of Florida and Texas A & M released the first St. Augustine decline resistant variety, "floratam", in 1975.
- ◆ In 1989, North Carolina State University released "Raleigh", which is also resistant to St. Augustine decline and is more cold-hardy than floratam.
- ◆ The University of Florida is now patenting new varieties of St. Augustine grass.

## 11-19. NEMATODE DISEASES

a. **Description/Development of Nematodes.** Nematodes are tiny, transparent, often-microscopic roundworms. Nematodes range from 1/50 to 1/8 inches in length. These worms reproduce by laying eggs, which hatch to release larvae. Larvae go through four molts before reaching adult size. Females may produce several hundred eggs, and the whole life cycle may be complete in five to six weeks if conditions are favorable.

b. **Nematodes and Turfgrass.** Most nematodes live on dead plants or animals, but about 50 species parasitize turfgrass roots. These nematodes are obligate parasites which must feed on living plants to grow and reproduce. Plant pathogenic nematodes can usually parasitize a variety of plants, including weeds. Nematodes can survive for long periods on stored food. Many nematodes can live in frozen soils and may pass the winter in living roots or dead plant material.

c. **Symptoms of Nematode Damage.** Symptoms of nematode damage include yellowing, wilting, apparent drought stress when the soil is well watered, and turf thinning. This damage is caused by nematodes feeding on the turf root system. Nematode damage may not be apparent until environmental stresses, such as drought, further weaken the turf. Damage often occurs in streaks or oval areas. Nematode-feeding leaves wounds in plant root systems. Bacteria and fungus colonize the wounded roots, causing further damage.

d. **Conditions for Development/Dissemination of Nematode Problems.** Nematodes thrive in warm temperatures, sandy soils, and moderate soil moisture.

- ◆ Nematodes do not thrive in heavy or compacted soils where soil oxygen may be restricted.
- ◆ Nematodes are relatively immobile in soil because of their small size. These pests spread by mechanical transfer of soil or water.

e. **Classification of Plant Pathogenic Nematodes.** Plant pathogenic nematodes are classified according to feeding habits as ectoparasites or endoparasites.

(1) Ectoparasitic nematodes. Ectoparasitic nematodes feed along the root surface. The nematode inserts a hollow, needle-like structure called a stylet into the root tissue. The nematode injects enzymes into plant cells and withdraws partly digested food. Ectoparasitic nematodes are more frequently damaging to turf than endoparasites.

(2) Endoparasites. Endoparasites burrow partially or totally into plants and feed from within. These nematodes also feed through stylets.

f. **Control.** Two nematicides, ethoprop and fenamiphos, are available for use on turf. These chemicals are organophosphates and are extremely toxic. Both are available as granules.

- ◆ Soil fumigants. Soil fumigants will control nematodes, but may only be used if total renovation is desirable, since the entire turf is killed.
- ◆ Nematicides and watering. Nematicides must be completely watered in to the soil to be effective. If the soil is aerated before applying nematicides, pesticide movement into the soil is enhanced.
- ◆ Other measures. Raising mowing height; deep irrigation; and balanced fertilization may keep turf growing through a nematode infestation.

- ♦ Organic fertilizers. Organic fertilizers may discourage the development of high parasitic nematode populations (although research data isn't conclusive).

#### Section IV. NON-INFECTIOUS DISEASES: BIOTIC AGENTS

### 11-20. GENERAL INFORMATION

**a. Biotic Agents.** Turfgrasses are often damaged by competition with living agents: weeds, moss, and algae. These agents don't cause true diseases, but the disorders caused by the agents may look like disease. Make a careful diagnosis to be certain the problem is a biotic agent rather than true disease.

**b. Abiotic Agents.** Abiotic agents are those which can damage turfgrass by chemical, physical, or mechanical factors in the environment. If these factors exist along with infectious agents, diagnosis of the cause of turfgrass is difficult.

### 11-21. BIOTIC AGENT: FAIRY RING

**a. Information.** A large number of basidiomycetes (fungi which bear spores on specialized, club-shaped hyphae called "basidia") cause fairy rings in turfgrasses. These fungi inhabit the thatch or the soil. Most of these fungi produce mushrooms, toadstools, or puffballs of various sizes and shapes.

**b. Symptoms.**

- ♦ Evidence of fairy ring includes circular or arc-shaped rings of darker green or faster growing grass in moist turf.
- ♦ Areas may be several meters in diameter. Mushrooms may be present.
- ♦ Mycelial growth prevents water infiltration, and toxins may be produced, causing turf death.

**c. Condition for Development/Dissemination.** Conditions which favor fairy ring

in turfgrass include thatch, sandy soils, low fertility, and moisture stress.

**d. Control.**

- ♦ Evacuation or soil fumigation. Fairy ring may be eradicated by excavation or soil fumigation. If excavation is chosen, the soil should be removed to a depth of 12 inches, and the excavation should extend 2 feet outside the ring. The excavated area should be refilled with clean soil and replanted.
- ♦ Aeration and deep watering. Since these heroic measures are impractical, most turfgrass managers use aeration and deep watering. The soil is core aerated, and then irrigated to a depth of four to six inches. The fungus does not die, but the grass continues to grow and symptoms are suppressed.

### 11-22. BIOTIC AGENT: SLIME MOLD

**a. Information.** Slime molds are fungi which colonize the surface of turfgrass leaves. The fungi do not cause plant disease, but the white, gray, purple, or brown patches caused by mold growth may cause alarm. The fungi use grass leaves and stems to support reproductive structures. These molds may occur on any turfgrass, since the grass is essentially used as an inert substrate.

**b. Symptoms.** Grass leaves are covered with white, gray, or purplish fungal patches.

- ♦ Some leaves may turn yellow due to heavy slime mold reproduction blocking sunlight. The grass is then susceptible to infection by pathogenic fungi.

**c. Conditions for Development/Dissemination.** Conditions which are favorable for slime mold include cool, wet weather and heavy thatch.

**d. Control.** Control is usually unnecessary. A hard stream of water will wash spore masses off the grass. Mowing also removes spore masses.

## Section V. NONINFECTIOUS DISEASES: ABIOTIC AGENTS

### 11-23. ABIOTIC AGENT: CHEMICAL AGENTS

a. **Pesticides.** Use pesticides IAW the directions on their containers. If the directions are not followed carefully, turfgrass plants may be killed or their growth retarded.

b. **Fertilizers.** Fertilizers applied incorrectly may damage turfgrass. Too much fertilizer can cause excessive growth. Fertilizer on wet grass leaves can cause salt burn.

c. **Nutrient Deficiencies.** Nutrient deficiencies cause direct metabolic damage to plants.

d. **Air pollution.** Air pollution, in sufficient concentrations, can damage plant metabolism. This damage is most common near metropolitan areas, factories, energy generation plants, and along busy highways.

### 11-24. ABIOTIC AGENT: PHYSICAL AGENTS

a. **Temperature.** Extremes of temperature, either high or low, may damage turfgrasses and all other plants. Turfgrass may be killed in cold weather by dehydration or direct tissue damage.

- ◆ **Dehydration.** Dehydration occurs when grass is growing in frozen soil without a snow cover. Direct tissue damage occurs when ice crystals form in plant cells. Ice crystals break through plant cell walls. Exposure to winter winds, sun, and cold weather affects winterkill.
- ◆ **High temperatures.** High temperatures can damage grass when the grass is unable to cool itself through evapo-transpiration. Temperatures under an object on the grass can be so high the grass is damaged. Lightning is a special form of high temperature damage.

b. **Water Deficiencies/Excess.** Water deficiencies, or excess, probably cause more damage to grass than any other abiotic factor. Often, these effects are difficult to separate from the effects of temperature.

c. **Shallow Soil.** Shallow soil can be a factor in turf damage. Soil over shallow rock formations or buried construction materials (a particular problem on many military installations) may dry quickly, and the grass may wilt much sooner than grass growing in deeper soils.

d. **Soil Compaction.** Soil compaction is a common cause of turf damage and damage to other plants, including trees.

- ◆ A healthy soil consists of about 50 percent solid material and about 50 percent pore space. Of the pore space, about half is filled with air, an essential for root growth and the growth of soil organisms.
- ◆ Heavily trafficked areas lose pore space, and soil air is restricted. This is a special problem on clay soils and on wet soils.
- ◆ Soil compaction is a particular problem when heavy machinery is used for mowing or turf cultivation, and where sports events or parades are conducted.

e. **Thatch.** Thatch is a layer of plant litter at the soil surface. The litter consists of partially decayed turf stems, roots, crowns, and leaves. Heavy thatch impedes the movement of water, fertilizer, air, and pesticides into the soil. The turf chokes itself to death. Turf roots tend to grow in the thatch layer, causing turfgrass to be susceptible to drought and temperature damage.

### 11-25. ABIOTIC AGENTS: MECHANICAL AGENTS

A number of mechanical agents can injure turfgrass.

a. **Mower Injury.** Mower injury occurs when dull mower blades, particularly rotary mower blades, shred and tear the grass blades instead of cutting the grass. Shredding the grass causes browning of the leaf tips and produces a large wound for fungus diseases to colonize.

**b. Leaf and Crown Bruises.** Leaf and crown bruises occur during turfgrass dormancy. Turfgrasses go dormant during freezing or very dry weather. Vehicle or foot traffic on the dormant grass damages the grass crowns and leaves. Damaged tissues turn brown and fail to grow when the grass breaks dormancy.

**c. Abrasion Injury.** Abrasion injury occurs when green grass is used heavily; for example on athletic fields. The affected leaves dry out and brown. Usually the turf crown is undamaged, and new leaves are soon produced. A similar injury occurs when mower blades are set too low and the grass is "scalped" so that yellow and brown stems are exposed. Frequent scalping can completely destroy patches of grass, causing replanting (and resetting the mower) to be necessary.

## Section VI. DISEASE CONTROL

### 11-26. PREVENTION

**a. Conditions Which Promote Disease.** For plants to become diseased, several conditions must be present—all at the same time:

- ◆ A susceptible host.
- ◆ Environmental conditions conducive to pathogen development.
- ◆ Aggressive pathogens. If any one of these conditions is missing, disease in plants will not develop.

**b. Factors To Inhibit Disease.** Sterilizing seedbeds and using high-quality seed, sod, or sprigs is helpful. Disease can also be inhibited by obtaining disease-resistant species and cultivars through local recommendations.

### 11-27. CULTURE

**a. Definition/Goal.** Cultural controls are aimed at changing the environmental conditions necessary for diseases to develop. A

further aim is the production of healthy, rapidly growing turf which can resist or "grow through" a disease infection.

**b. Temperature.** Temperature effects the growth of pathogens and turfgrasses. Most disease problems occur when the grass growth is slowed and fungi are growing rapidly. For example, fungi which thrive in cool temperatures cause disease in the fall when grass growth is slowed. The manager has very few opportunities to control temperature. Awareness of the effects of temperature is the best weapon.

**c. Humidity.** Leaf wetness is essential for the germination of fungal spores. The spores require about 12 hours of moisture. This period of leaf wetness is controlled by watering in early morning, improving air circulation (removing obstructions to air movement), mowing at the suggested height, sowing seeds at the recommended rate, knocking dew off the grass in early morning, and using powerful fans during humid weather.

**d. Water.** Soil moisture is important to turfgrass growth and the growth of pathogens. Turfgrasses grow most successfully in well-drained soils. Turfgrass should be watered in early morning to avoid long periods of leaf wetness. Irrigation should be applied as infrequently as possible, but enough water should be applied to wet the entire root zone. Irrigation should be applied to prevent wilt.

**e. Light.** Certain diseases are associated with low light intensity. Powdery mildew, rusts, and some leaf spot diseases are most severe in shady locations. Light intensity can be controlled by tree removal or pruning, although this is often impractical or undesirable.

**f. Fertilizers and Soil Reaction.** Balanced nutrition is necessary for rapid turf growth and disease resistance; however, overly high nutrition levels (especially high nitrogen) are undesirable and contribute to the risk of diseases such as pythium, brown patch, and typhula blight, among others. Soil pH should ideally be maintained between six and seven, since the activity of beneficial microbes is maximized at this level. Decomposition of thatch is most rapid at this pH.

**g. Pesticides.** Unfortunately, pesticides do not kill target pests alone. Overuse of pesticides can disrupt the entire ecology of the soil by killing beneficial soil insects, earthworms, nematodes, and fungi. Since many soil organisms compete with pathogens, decay thatch, or actually feed on pathogens, pesticide overuse can end up contributing to future disease problems.

**h. Mowing Practices.** Mowing turfgrass contributes to turfgrass diseases. Mowing opens wounds for microbes to colonize, spreads fungal spores, and removes the leaf area needed for turf growth. The most highly managed turf is the most susceptible to disease. Many diseases can be controlled by slightly raising the mowing height (when this is practical).

**i. Thatch Control.** Thatch accumulation is a symptom of an imbalance between turf growth and tissue decomposition. Heavy thatch contributes to several turf diseases. Thatch can be controlled by proper fertilization and irrigation, maintaining pH between six and seven, and by mechanical removal, aeration, and topdressing. Repeated pesticide application may lead to thatch buildup.

#### **11-28. ABIOTIC AGENTS: CHEMICAL CONTROL**

Fumigants, fungicides, and nematicides are all pesticides that control turfgrass diseases.

**a. Fumigants.** These toxic gases kill everything in their path: weeds, insects, nematodes. This type of control should be used only in areas where other types of control have been ineffective. Fumigants are most often justified on bowling greens or high-value golf greens.

**b. Contact Fungicides.** Fungicides are made with two purposes: (1) to kill certain groups of fungi or (2) to render certain groups of fungi temporarily incapable of growth. Contact fungicides kill mycelium or fungi spores when the fungicide touches the infected turf. Names of common fungicides include chloroneb, maneb, thiram, and iprodione.

**c. Systemic Fungicides.** Most systemic fungicides are not toxic enough to kill

fungi, or the plant would also be killed. These pesticides are actually fungistats. The fungi are not killed, but fungal growth is restricted. Most systemic fungicides move only upward in plants, so the chemical must be applied to the right part of the plant. Root or stem diseases cannot be controlled with a foliar application of systemic fungicide.

**d. Systemic Fungicide: Benzimidazole Derivatives.** Examples of this fungicide include benomyl and methyl thiophanate. Characteristics are as follows:

- ◆ The fungicide only moves upward in plants.
- ◆ It must be drenched into the soil to control root or stem pathogens.
- ◆ Overuse may lead to resistance.
- ◆ It is not toxic to pythium or several other fungal species.

**e. Systemic Fungicide: Sterol Inhibitors.** Examples include cyproconazole, fenarimol, and prochloraz. Look at these characteristics:

- ◆ The fungicide is mobile in plants.
- ◆ It prevents ergosterol production in sensitive fungi.

**f. Systemic Fungicides: Other Chemical Classes.** Examples include fosetyl-aluminum, metalaxyl, and propamocarb.

#### **11-29. CLOSING**

The key to control of turfgrass diseases is constant surveillance to detect problems early. Proper management of turfgrass reduces disease problems because healthy grass is better able to resist disease organisms. If disease control becomes necessary, stress cultural controls. Cultural controls are safer and more permanent than pesticides.

## EXERCISES, LESSON 11

**REQUIREMENT.** The following exercises are to be answered by selecting the correct letter, completing the incomplete statement, or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

**Match the diseases in Column A  
with the corresponding causal agents in Column B.**

### Column A

- \_\_\_ 1. St. Augustine decline.
- \_\_\_ 2. Fairy ring.
- \_\_\_ 3. Rhizoctonia brown patch.
- \_\_\_ 4. Slime mold.

### Column B

- a. Causal agents are basidiomycetes which inhabit the thatch or soil, producing visible mushrooms, toadstools, or puffballs of various shapes and sizes.
- b. Causal agent is a complex virus which results in chlorotic mottle or mosaic on turfgrass leaf blades. Masy kill the entire lawn as early as three years after the first symptoms appear.
- c. Causal agents are fungi which colonize the surface of turfgrass leaves. Fungi use grass leaves and stems to support their reproductive structures.
- d. Causal agent is a fungus which infects grass tissue at the edge of a patch, affecting all grass blades at the same time.

**Match the diseases in Column A  
with the corresponding symptoms in Column B.**

**Column A**

- \_\_\_ 5. Copper spot.
- \_\_\_ 6. Pink snow mold.
- \_\_\_ 7. Powdery mildew.
- \_\_\_ 8. Leaf smuts.

**Column B**

- a. Narrow, yellow-green streaks. Streaks rupture, releasing black, dusty spores. Leaves split or shred between veins and die.
- b. Some leaves and tillers may die; then, turf loses its density. On bluegrass, whitish mycelia appears powdery or dusty.
- c. Scattered, circular patches two to seven centimeters in diameter appear in the turf. The infected turf changes color from salmon to copper.
- d. Infected turf changes rapidly from orange-brown to dark brown to light gray. On closely mowed turf, the outer edge of the turf may have a greenish-black, water-soaked appearance.

**Match the diseases in Column A  
with the corresponding pest management technique in Column B.**

**Column A**

- \_\_\_ 9. Red-thread effects.
- \_\_\_ 10. Typhula blight.
- \_\_\_ 11. Rusts.
- \_\_\_ 12. St. Augustine decline.

**Column B**

- a. Resistant varieties are the only form of control.
- b. Avoid management practices which stress turf.  
Apply balanced fertilizer and irrigate deeply.  
Apply appropriate fungicides.
- c. Apply nitrogen fertilizer.
- d. Reduce nitrogen levels in late autumn. Keep grass  
closely mowed.

**END OF LESSON EXERCISES**



## LESSON ASSIGNMENT

<b>LESSON 12</b>	--	Natural Resources Conservation Programs.
<b>LESSON ASSIGNMENT</b>	--	Paragraphs 12-1 through 12-10.
<b>TERMINAL LEARNING OBJECTIVE</b>	--	Information gained in this lesson should enable you to describe an installation natural resources conservation program IAW DoD Directive 4700.4.
<b>SPECIFIC LESSON OBJECTIVES</b>	--	After completing this lesson, you should be able to:  12-1. Select three types of natural resources conservation programs that may be found at an installation and what each contains.  12-2. Select procedures and design an installation natural resources conservation program.
<b>SUGGESTION</b>	--	After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

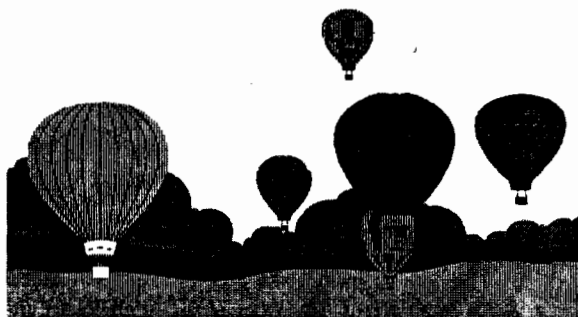
## LESSON 12

### NATURAL RESOURCES CONSERVATION PROGRAMS

#### 12-1. INTRODUCTION

The Department of Defense owns or controls more than 31,000,000 acres of land in the United States. This is an area larger than the state of Tennessee. DoD properties include both improved and relatively undisturbed lands in a wide variety of habitats. There are DoD installations in forest, prairie, desert, and marine environments. Because it has such extensive ownership of relatively undisturbed land, DoD has stewardship for many habitats critical to the survival of endangered and threatened species. The DoD outleases much of its land holdings to agricultural interests, and markets much of its renewable resources such as timber. Also, DoD

lands provide the public with outdoor recreation opportunities such hunting and fishing. As a pest management professional, it is your responsibility to ensure that your activities do not adversely affect desirable species. Your actions may also help to ensure a sustained harvest of commercially valuable resources and preserve rare and endangered species.



## 12-2. NATURAL RESOURCES DEFINITION

Natural resources may be defined as the products of nature and their environment of soil, air, and water to include plants and animals occurring on grassland, rangeland, cropland, forests, lakes, and streams.

## 12-3. NATURAL RESOURCES MANAGEMENT PROGRAM

a. **Requirement.** DoD Directive 4700.4 requires every DoD installation to have a Natural Resources Management Program that is implemented through an integrated Natural Resources Management Plan (NRMP). The NRMP guides planners and implementors of mission activities as well as natural resources planners. The NRMP must be coordinated with appropriate Federal, state, and local officials with interest or jurisdiction, and with planners of DoD activities that impact on natural resources. The NRMP is reviewed and approved every five years.

b. **NRMP Criteria.** The NRMP must meet the following criteria:

- ◆ Addresses natural resources of critical or special concern from a technical and policy standpoint.
- ◆ Methodologies shall sustain the capabilities of natural resources to support military activities.
- ◆ Includes current inventories and conditions of natural resources; goals; management methods; schedules of activities and projects; priorities; responsibilities of installation planners and decision makers; monitoring systems; and land use restrictions, limitations, and capabilities.
- ◆ Each plan segment or component (i.e., land, forest, fish and wildlife, and outdoor recreation) exhibits compatible methodologies and goals.
- ◆ The plan must be compatible with the installation master plan and pest

management program under DoD Instruction 4150.7.

## 12-4. NRMP FUNCTIONAL AREAS

The integrated NRMP shall include the following functional areas, as appropriate:

- ◆ Land management.
- ◆ Forest management.
- ◆ Fish and wildlife management.
- ◆ Outdoor recreation.

## 12-5. LAND MANAGEMENT

### a. Land Management Policies.

(1) DoD lands shall be managed to support military activities, improve the quality of land and water resources, protect wetlands and floodplains and their functions, abate nonpoint sources of water pollution, conserve lands suitable for agriculture, control noxious weeds, and control erosion.

(2) Costs for maintaining grounds shall be minimized by providing the least amount of mowed areas and special plantings necessary to accomplish management objectives and by the use of low maintenance species, agricultural and grazing outleases, wildlife habitat, and tree plantings.

(3) Appropriated funds as well as revenue from agriculture and grazing outleases shall be used to fund the preparation and implementation of the NRMP.

(4) Land management plans shall address soils, water resources, soil and water conservation, wetlands and floodplains, grounds maintenance, landscaping, agricultural uses and potential fire management, rangeland conditions and trends, areas of special interest and management for multiple uses, as appropriate.

(5) Soil capabilities, water management, landscaping, erosion control, and conservation of natural resources shall be included in all site feasibility studies and in project planning, design, and construction. Appropriate conservation work and associated

costs shall be included in project proposals and construction contracts and specifications.

(6) Irrigation will be limited to areas where it is essential to establish and maintain required vegetation and to support agricultural outleases when contracts allow it.

(7) Natural resources conservation measures shall be included in outlease provisions.

(8) Landscaping will be functional in nature, simple and informal in design, compatible with adjacent surroundings, and complimentary to the overall natural setting of the area.

(9) Land conditions, soil capability, and erosion status shall be monitored for all lands subject to disturbance (e.g., maneuver areas, commercial forest areas, and agricultural outleased areas).

**b. Grounds Descriptions and Required Data.** The Land Management Plan should contain the following information, as appropriate:

- ◆ Total acreage of improved grounds, and acreage of irrigated and unirrigated grounds.
- ◆ Total acreage of semi-improved grounds, and acreage that is mowed and unmowed. It should also indicate policies for noxious weed control.
- ◆ Total acreage of unimproved grounds and acreage that is mowed. It should also indicate noxious weed control and other maintenance performed.

## **12-6. FOREST MANAGEMENT**

### **a. Forest Management Policies.**

(1) DoD forest lands shall be managed for sustained yield of quality forest products, watershed protection, wildlife habitat, and other uses that can be made compatible with mission activities.

(2) Commercial activities must be commensurate with potential financial returns. All profits from timber sells will go into the military department's forestry account.

(3) Forest products will not be given away, abandoned, carelessly destroyed, or used to offset contract costs. They will not be traded for products, supplies, or services. Noncommercial or edible forest products may be harvested by individuals if that use is addressed in the forest management plan.

(4) Planned commercial sale of forest products shall continue on excess land until its disposal or transfer occurs. Clearcutting is prohibited on forested areas slated to be public parks or used for outdoor recreation. However, thinning, intermediate cuttings, and salvage cuttings are allowed if the management plan calls for such activities within five years.

**b. Forest Descriptions and Required Data.** The Forest Management Plan should contain the following information, as appropriate:

(1) Outline all planted areas including:

- ◆ Total forest land managed.
- ◆ Acres reforested by planting.
- ◆ Acres reforested by seeding.
- ◆ Acres to be reforested.
- ◆ Calculated annual harvest for the next five years.
- ◆ Estimated operating cost for the next five years.
- ◆ Forest fire record.

(2) Name and describe the distinct forest types common to the natural woodland.

(3) Describe forest management practices, to include:

- ◆ Species to be grown, reason for selection, years to harvest, and number of years for cutting cycle between harvests.
- ◆ Procedures for conversion of unmerchandisable forest species to desirable species (e.g., prescribed burning, herbiciding, and girdling).
- ◆ Timber plantings for next five years including location, species and spacing, and age of planting stock.

## 12-7. FISH AND WILDLIFE MANAGEMENT

### a. Fish and Wildlife Management Policies.

(1) Suitable lands and waters will be managed to conserve wildlife resources for the benefit of the public. Nongame as well as game species shall be considered when planning activities.

(2) Fish and wildlife conservation shall be a consideration in all installation site feasibility studies and project planning, design, and construction.

(3) Endangered and threatened species and their habitats must be protected and managed IAW the Endangered Species Act. Management plans for installations with endangered species shall include:

- ◆ Coordinated protection and mitigation measures.
- ◆ Appropriate management practices and procedures necessary to enhance the population of endangered species
- ◆ Procedures and responsibilities for consulting with the US Fish and Wildlife Service prior to funding or conducting any action likely to affect a listed species or its critical habitat.

(4) Hunting, fishing, and trapping may be permitted within the carrying capacity of installation habitats. Wildlife harvesting will be IAW the laws and regulations of the state or territory in which the installation is located.

(5) Hunting, fishing, and trapping fees may be collected, as can additional recreation fees under policies in DoD Directive 1015.6. Fees collected under the fish wildlife management program shall only be used to defray costs of the fish and wildlife management program at the installation collecting the fees.

(6) DoD officials in consultation with the Fish and Wildlife Service and host state shall determine the suitability of the installation for fish and wildlife management and classify it as one of the following:

- ◆ Category I. Installations with land and water resources suitable for fish and wildlife conservation are listed as Category I. Each Category I installation must maintain a wildlife management plan.
- ◆ Category II. Installations that lack adequate land and water resources for feasible fish and wildlife conservation are designated this category.

**b. Required Data for the Fish and Wildlife Management Plan.** The Fish and Wildlife Management Plan should contain the following information, as appropriate:

- ◆ Denote fish game species present.
- ◆ Denote non-game birds common to the area.
- ◆ Indicate endangered species present.
- ◆ Describe fish and wildlife potential on the installation including:
  - Habitat trends (e.g., vegetation important to wildlife).
  - Fish and wildlife population trends.
  - Game responses to past land use programs.
  - Potential days of hunting and fishing.

## 12-8. OUTDOOR RECREATION

### a. Outdoor Recreation Policies.

(1) Conservation of outdoor recreation resources must be a consideration in all installation plans, programs, site feasibility studies, and project planning and design.

(2) Installations having resources suitable for outdoor recreation other than hunting, fishing, and trapping should develop cooperative agreements or plans with other Federal agencies and state agencies to develop and manage these resources.

(3) Public access to DoD properties for outdoor recreation shall be allowed whenever it is compatible with public safety and missions activities.

(4) User fees may be collected to recover the cost of managing natural resources for outdoor recreation.

**b. Required Data for the Outdoor Recreation Plan.** The Outdoor Recreation Management Plan should contain the following information, as appropriate:

(1) Inventories, trends, and management of resources suitable for outdoor recreation.

(2) Aesthetic value of natural resources.

(3) Potential user groups and access policies.

(4) Multiple use management strategies.

## 12-9. ITEMS COMMON TO MOST OF THE NRMP

Information that effects all functional areas of the Natural Resources Management Program and should be included in the integrated NRMP includes:

**a. Installation Climate.** This includes the average monthly and annual rainfall; average monthly and annual temperatures; and average spring and fall frost dates.

**b. Installation Topography.** The description should include topographical maps.

**c. Soil Descriptions.** This includes the classification of the various soils on the installation; chemical analyses of improved grounds soils; and mechanical analyses of improved grounds surface soils.

**d. Natural Vegetation.** This should include a list of the common and scientific names of the principle trees and shrubs prior to cultivation; native grasses present in undisturbed areas; native species important for wildlife food and cover; any endangered plant species and their location; and noxious and poisonous plants.

**e. Drainage System.** A description of the installation drainage system should include the following:

- ◆ Drainage map showing contour elevations.
- ◆ History of flooding in built-up areas.
- ◆ Width, depth, side slope grade, and percent fall of principal channels.
- ◆ Type of storm drainage used (i.e., flume, spillways, drop inlets, etc.).
- ◆ For tile drainage, identify areas with field tile, outlet locations, and kind and size of tile.
- ◆ Identify marsh areas.



## 12-10. CONCLUSION

The DoD, with its vast land holdings, has ownership for much of this country's renewable natural resources. These resources are a source of revenue through commercial timber sales and agricultural outleases. The DoD also provides the public with outdoor recreational opportunities through hunting, fishing, camping, hiking, and other outdoor pursuits. The DoD controls habitats critical to the survival of numerous endangered plant and wildlife species.



As a pest management professional, your activities have the potential to be detrimental to natural resources. Conversely, if used carefully as part of an integrated Natural Resources Management Program, your professional activities can help to assure that these resources are available for future generations.



## EXERCISES, LESSON 12

**REQUIREMENT.** The following exercises are to be answered by completing the incomplete statement or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

1. Natural resources may be defined as the products of nature and their environment of soil, air, and water, which include \_\_\_\_\_ and \_\_\_\_\_ occurring on grassland, rangeland, cropland, forests, lakes, and streams.

2. The four functional areas of an integrated Natural Resources Management Program are land management, forest management, fish and wildlife management, and \_\_\_\_\_

3. How can revenue raised from hunting and fishing be used? \_\_\_\_\_

4. Which of the following information is not common to all functional areas of an integrated Natural Resources Management Plan?

- a. Installation climate.
- b. Soil descriptions.
- c. Installation topography.
- d. Introduced cultivated plants.

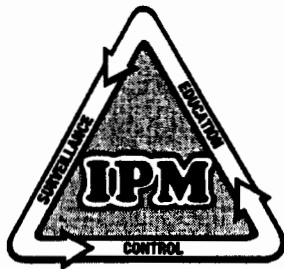
5. Data for the Fish and Wildlife Management Plan on an installation should contain these four elements of information:

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_

6. On an installation, user fees may be collected to recover the cost of managing natural resources for outdoor recreation.

- a. TRUE.
- b. FALSE.

**END OF LESSON EXERCISES**



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## LESSON ASSIGNMENT

<b>LESSON 13</b>	--	Turfgrass Management.
<b>LESSON ASSIGNMENT</b>	--	Paragraphs 13-1 through 13-13.
<b>TERMINAL LEARNING OBJECTIVE</b>	--	Information gained in this lesson should enable you to utilize modern turf management strategies to produce a healthy, fast-growing turf which will limit weed, insect, and disease problems.
<b>SPECIFIC LESSON OBJECTIVES</b>	--	After completing this lesson, you should be able to:  13-1. Identify the characteristics of turfgrasses.  13-2. Discuss the management practices necessary to successful turfgrass culture.  13-3. Develop grass mowing programs tailored to specific turfgrass situations.  13-4. Identify turfgrasses suitable for specific climates and uses.
<b>SUGGESTION</b>	--	After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 13

### TURFGRASS MANAGEMENT

#### Section I. GENERAL INFORMATION

#### 13-1. INTRODUCTION

Turfgrasses have been used for almost 2,000 years as an ornamental plant of unique qualities. Turfgrass is used to beautify suburban lawns, parks, and playgrounds. Grasses are used as a surface for many popular sports, including golf, lawn bowling, baseball, football, soccer, tennis, and polo, among others. Turfgrass management is a billion dollar industry in the United States and around the globe. A notable development in recent years is the explosion of the golf course industry in Asian

countries where golf course construction is taking up former farmlands at a lightning pace.

#### 13-2. BIG BUSINESS

Turf management is also big business for the DoD. Virtually every installation, CONUS or OCONUS, has its golf course, parade fields, athletic fields, parks, roadsides, and other areas where turfgrass is grown at varying levels of intensity. Golf courses alone account for about 50 percent of DoD pesticide use, so turfgrass culture is a pest management issue. Using modern techniques of turf management means reducing pesticide use to the minimum.

#### 13-3. TURFGRASS CHARACTERISTICS

a. **Information.** There are hundreds of grass plants, but very few are suitable for turf. A turf is a covering of vegetation (not always grass)

plus the matted, upper soil level, filled with roots and/or rhizomes. Most grasses grow in bunches and do not form the matted growth of a true turf.

**b. Characteristics.** Characteristics of turfgrasses include:

- ◆ Growth habitat. Low growing, frequently prostrate or creeping growth habit.
- ◆ Herbaceous (soft) tissue. Turfgrasses do not produce persistent woody tissue.
- ◆ Perennial life cycle. A few turfgrasses are annual plants, but these are mostly used for overwintering or as a temporary ground cover.
- ◆ The crown. Turfgrasses initiate root, stem, and leaf growth from an area called the crown. The crown is the most vital part of the plant, because all growth originates from this tissue. If the root system, leaves, or both, die; the plant can still survive if the crown tissues remain viable. The crown is located at ground level, which allows us to mow turfgrasses without harming the plant.

#### **CHARACTERISTICS OF TURFGRASS**

- ◆ Low growing.
- ◆ Herbaceous (soft) tissue.
- ◆ Perennial life cycle.
- ◆ Root, stem, and leaf growth from the plant crown.

#### **13-4. TURFGRASS FUNCTIONAL IMPORTANCE**

The recreational and aesthetic value of turfgrass has already been discussed. These grasses are also used for a number of functional purposes. These functions include:

- ◆ Control of soil erosion.

- ◆ Elimination of dust and mud problems around homes, schools, businesses, and factories.
- ◆ Reduction of glare, noise, air pollution, heat buildup, and visual pollution. The cooling effect of turfgrass is usually vastly underestimated. A normal residential lawn has the same cooling capacity as several tons of air conditioning.
- ◆ Soil stabilization along roadsides, airfields, etc.

#### **13-5. COMMON TURFGRASSES**

Turfgrasses commonly used in the DoD include the following:

**a. Kentucky Bluegrass.** Kentucky bluegrass is a cool-season perennial turfgrass. It has dark, green-folded leaves. This grass is strongly rhizomatous; that is, it has a horizontal, underground root stem. This grass produces shoots above ground and sends out roots below ground.

**b. Tall Fescue.** Tall fescue is a coarse-textured, cool-season perennial bunchgrass. It has leathery, pointed, and deeply ridged leaves. A very hardy grass, it is an easily maintained utility grass.

**c. Fine Fescues.** Fine fescues are a group which includes the hard fescues, sheep fescue, creeping red fescue, and other species. These grasses are cool season perennials with narrow, dark green foliage. They produce short rhizomes (horizontal sub-surface stems) and spread by producing rhizomes and many tillers. Creeping red fescue is useful in shady areas.

**d. Perennial Ryegrass.** Perennial ryegrass is a coarse, short-lived, cool-season bunch grass. This grass is often used in warm climates to cover bermudagrass greens during winter.

**e. Creeping Bentgrass.** Creeping bentgrass is a fine-textured, cool-season perennial. This grass produces creeping stolons (horizontal, above-ground stems). Leaves are short and soft. Creeping bentgrass is considered to be the premier species for golf greens.

f. **Bermudagrass.** Bermudagrass is a warm-season grass which spreads with both stolons and rhizomes. This grass is very aggressive and fast-growing, especially in full sunlight. Drought tolerant, common bermuda produces viable seeds, but hybrids are propagated with plugs, sprigs, or sod.

g. **Zoysiagrass.** Zoysiagrass spreads with stolons and rhizomes. This grass is similar to bermudagrass in appearance, but stiffer and more compact. It is propagated with sod or plugs and is very tolerant of shade.

h. **St. Augustine Grass.** St. Augustine grass is a very coarse, stoloniferous, warm-season perennial. Blunt tipped with light-green leaves, this grass is very useful in shade. St. Augustine grass is susceptible to chinchbugs, nematodes, and various diseases.

i. **Bahiagrass.** Bahiagrass is a very coarse-textured, warm-season perennial. It spreads with short, thick rhizomes. Bahiagrass is very drought tolerant, tolerates infertile soil, and has distinctive "V"-shaped seed heads.

## Section II. MANAGEMENT PRACTICES

### 13-6. TURFGRASS AND THE ECOSYSTEM

A stand of turfgrass constitutes an ecosystem, albeit a very artificial ecosystem. In fact, most of our turfgrasses would not survive for long without human management. Better adapted plants would soon invade turfgrass stands without the constant vigilance of the manager. Turfgrass culture is a constant struggle to maintain a static situation in which soil, moisture, sunlight, and pest pressure are controlled so that turfgrasses can flourish. Human inputs to this artificial ecosystem are considerable. Some common turfgrass management practices are discussed in the following paragraphs.

### 13-7. MOWING

Mowing is a systematic removal of a portion of the turfgrass leaf. Mowing turf is a

relatively new practice in human history. The medieval English refer to "lawn gardens" in their gardening literature. Apparently these lawns were mowed with scythes. Golf, which now requires the most sophisticated mowing equipment, began as a game played on natural turfs which were "mowed" by sheep grazing. The first mowing machine for turf was patented in 1830 by Edwin Budding of Gloucestershire, England. Modern mowing equipment is incredibly complex and precise.

a. **Mowing Height.** Mowing height is varied according to turf species, use of the turf, and growing conditions. Some turfgrasses, such as bermudagrass, bentgrass, perennial ryegrass, and (to a lesser extent) bluegrasses can tolerate very close mowing. Other species, such as tall fescue and St. Augustine grass, cannot withstand close mowing. No more than 30 to 40 percent of the leaf height should be removed at one mowing.

b. **Mowing Frequency.** Mowing frequency should be varied according to turf growth rate, mowing height, and use of the turf. Fine textured turf, i.e. putting greens, may only be achieved through frequent mowing. Longer intervals between mowing increase turf vigor, as long as no more than 40 percent of the leaf is removed at one mowing.

### 13-8. MOWING EQUIPMENT

Mowing equipment can be divided into four main types by examining the type of blade used to cut the grass.

a. **Reel Mowers.** These mowers cut by pulling grass blades across a bed knife. The reel guides the grass blades into the cutting blade. Reel mowers produce a scissors-type cut, since the grass is cut between the two blades. Reel mowers are preferred when a close, even cut is desired. Reel mowers cannot effectively mow tall grass or operate on rough surfaces.

b. **Rotary Mowers.** Rotary mowers cut grass with the impact of a horizontal knife which rotates at great speed. These mowers are not adaptable to quality mowing at low cutting heights (below one inch). Rotary mowers can be used to cut tall grass on varying terrain. The blades must be kept sharp, or the dull blades

tear grass instead of cutting. The mutilated grass blades turn brown and have an unattractive appearance. Rotary mowers should be used with great care to avoid accidents.

**c. Vertical or Flail Mowers.** These mowers cut by impact of vertical, usually free-swinging knives, much as rotary mowers. The quality of the cut depends on the number of knives per foot of cut and the sharpness of the knives. Flail mowers are not usually used for quality mowing, but are extremely useful for vegetation control, roadside mowing, etc. Vertical or flail mowers do not pose the same safety risk as rotary mowers.

**d. Sickle-bar Mowers.** Sickle-bar mowers cut by the scissors action of a horizontal, reciprocating knife across stationary plates (it's easier to visualize the knife sliding back and forth across the stationary, toothed, plates). These mowers are useful along roadsides, steep slopes, and waterways where grass is cut one to four times per year. Unfortunately, the mower leaves mowed grass in a swath rather than spreading out the clippings. A mowed area tends to resemble a hay field.

### 13-9. FERTILIZATION

Fertilization is the addition of plant nutrients to the turfgrass. See lesson eight for a detailed discussion of plant nutrients. A fertilization program should be based on turfgrass species, soil type, and local conditions.

- ◆ Obtain and use a soil test.
- ◆ Test the soil where grass is intensively cultured once or twice per year.
- ◆ Look for visual symptoms of nutrient deficiencies.
- ◆ Adjust soil pH to 6 to 6.5, if possible.

### 13-10. IRRIGATION

**a. Definition.** Irrigation is the application of water to supplement natural precipitation. The water use rate for turfgrass varies, depending on species, humidity, growth

#### **MOWING EQUIPMENT CLASSIFIED BY BLADE**

- |                                |   |
|--------------------------------|---|
| ◆ <b>Reel mowers</b>           | Cut by putting grass blades across a knife blade. Produces a scissors-type cut.   |
| ◆ <b>Rotary mowers</b>         | Cut with horizontal knife rotating at high speed. Use to cut tall grass on varying terrain.   |
| ◆ <b>Vertical/Flail mowers</b> | Cut by impact of vertical, free-swinging knives. Used for vegetation control, roadside mowing, etc.   |
| ◆ <b>Sickle-bar Mowers</b>     | Cut by scissors action of a horizontal, reciprocating knife across stationary plates. Use along roadsides, steep slopes. Leaves mowed grass in a swath. |

rate, and so on. Most turfgrasses are believed to use between 0.1 and 0.3 inches per day, with usage up to 0.45 occurring in certain circumstances. Water usage per season depends on the length of the growing season. In most locations, natural water supply is not sufficient for plant needs throughout the entire season.

**b. When to Irrigate.** Irrigation water is applied whenever water use exceeds water supply. A variety of moisture testing devices are used to determine the level of moisture in the soil and thus plan irrigation. It's possible to use "foot printing" to time irrigations. Dry grass loses turgor pressure in leaf cells and doesn't spring back after being pressed down. If foot prints are visible after walking across the grass, it's time to water.

**c. How Frequently.** Irrigate as infrequently as possible (without allowing the grass to wilt) and deeply.

- ◆ The root zone should be filled with water.
- ◆ The amount of water required to fill the root zone depends on soil type. Sandy soils hold much less water than clays or organic soils.
- ◆ Irrigate in early morning so the grass leaves can dry during the day. Wet grass leaves are a perfect environment for fungal disease.

**d. How Much.** Adjust irrigation quantities to avoid runoff. Water is costly, and runoff water also carries dissolved nutrients and pesticides.

### 13-11. CULTIVATION

Cultivation is usually considered an agricultural practice. The word conjures up a vision of a tractor pulling a harrow through a dusty field, turning the soil, uprooting weeds. One pass across a golf course using such equipment would utterly destroy the turf. Turf managers cultivate by selectively tilling the turf without destroying sod characteristics. Some common methods of turf cultivation are discussed in the next paragraphs.

**a. Core Aeration.** Core aeration is the use of a hollow tine or spoon to remove a soil core and leave a hole in the soil. Usually aeration tines are 1/4 to 3/4 inches in diameter, with the smaller diameter tines used on sensitive areas such as golf greens. The core removal opens up the soil to allow increased penetration of air and water. The desired effect is improved root depth and root density.

- ◆ Coring should be accomplished when the soil is moist, but not wet, and the turf is actively growing.
- ◆ Soil cores can be removed, or broken up and worked into the turf.
- ◆ Topdressing (a light covering of sand) is usually applied within a week of aeration,

to fill and level the depressions remaining in the soil.

- ◆ Germination of weed seeds may follow coring, so a herbicide may be necessary.

**b. Grooving.** Grooving is the use of vertical knives to slice through the turf and into the soil. The knives can cut down to four inches deep in the soil. This should be done when the soil is fairly dry. Thatch control is the objective.

**NOTE:** Thatch is a layer of dead and living stems and roots which develops between the soil surface and the green vegetation.

When the thatch builds up to excessive levels, disease and insect problems, dry spots, decreased resistance to drought, and other problems result.

**c. Slicing.** Slicing is deep, vertical cutting with disks or V-shaped knives mounted on wheels. The slicing operation loosens the soil, but does not remove a core.

**d. Spiking.** Spiking is shallow perforation of the soil with solid tines or blades. The objective is increased penetration of water and air. Spiking is less effective than core aeration, but is less disruptive on a golf green or tee.

**e. Forking.** Forking is the use of a fork or tine to punch small holes in the sod. The tines are mounted on a weighted drum or wheel.

**f. Vertical Mowing.** Vertical mowing is the use of vertically operated blades of wire tines which cut into the turf perpendicular to the soil surface. The objective is thatch removal or turf thinning (for renovation).

**g. Topdressing.** Topdressing is the application of a thin layer of soil (usually sand) to the turf. The objective is levelling, thatch control, modification of soil, and winter protection of sensitive turf. The thin soil layer provides certain nutrients which stimulate microbial growth. Microbes feed on thatch and control thatch buildup.

## **MANAGEMENT PRACTICES NECESSARY FOR SUCCESSFUL TURFGRASS CULTURE**

- ◆ **Mowing**      ☞ Proper height according to turf species.  
Frequency according to turf growth rate,  
mowing height, and turf use.
  
- ◆ **Mowing equipment**      ☞ Select one of the following type mowers  
according to the turf and its area:
  - Reel mower.
  - Rotary mower.
  - Vertical or flail mower.
  - Sickle-bar mower.
  
- ◆ **Fertilizing**      ☞ Add nutrients.
  
- ◆ **Irrigating**      ☞ Add water when water use exceeds water  
supply. Water deeply and as infrequently as  
possible, avoiding runoff.
  
- ◆ **Cultivating**      ☞ Select the appropriate method from the  
following:
  - Core aerating - Opens soil to allow  
increased penetration of air and water.
  - Grooving - Vertical knives slice through  
the turf and into the soil; objective is  
thatch control.
  - Slicing - Deep, vertical cutting with disks  
or V-shaped knives. Loosens soil but  
does not remove the core.
  - Spiking - Shallow perforation of soil to  
increase water and air penetration.
  - Forking - Holes punched in the sod.
  - Topdressing - Application of a thin layer  
of soil (usually sandy) to turf for leveling,  
thatch control, soil modification, and winter  
protection of sensitive turf.

## 13-12. ESTABLISHMENT

Many turf problems stem from poor establishment. If the soil is not correctly prepared, leveled, and drained, the grass will never grow properly. Turfgrass is established from seeds or vegetative material such as stolons, plugs, or sod. Follow these establishment steps:

### Step 1. Prepare the seedbed.

- ◆ Level the soil. Crown the fields so water will run off the surface.
- ◆ Remove weeds and rocks.
- ◆ Apply fertilizer and lime, if necessary.
- ◆ Correct soil drainage, if necessary.

### Step 2. Seed.

- ◆ Apply pure seed at recommended rates. Exceeding recommended rates creates too many leaves per area, reduces air movement, and increases the potential for disease.
- ◆ Cover seeds to a depth of 0.8 to 1.5 mm).

- ◆ Lightly roll the soil to ensure good contact between seed and soil.
- ◆ Mulch with clean (weed free) straw or other material. Water lightly every day until seeds are established.

### Step 3. Plant vegetative material (sod, plugs, sprigs, or stolons).

- ◆ Plant fresh material.
- ◆ Lightly roll to insure good soil contact.
- ◆ Immediately irrigate and water lightly every day until established.

## 13-13. CLOSING

Managing pests in turfgrass is not only a matter of choosing the right pesticide. The objective should be to produce a healthy, deep-rooted turf which resists insects and diseases. Pesticides are used to restore an ecological balance which has been lost. When faced with a pest problem, the turf manager should try to determine the underlying cause, which may be nutrient imbalance, soil compaction, thatch buildup, or a hundred other factors. Treatments should be planned to address not only the symptom, but the cause.

### EXERCISES, LESSON 13

**REQUIREMENT.** The following exercises are to be answered by completing the incomplete statement or by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to the Appendix and check your answers.

1. Turf may be defined as \_\_\_\_\_  
\_\_\_\_\_
2. Why is the crown the most valuable part of the turfgrass plant? \_\_\_\_\_  
\_\_\_\_\_
3. Imagine this. In a turfgrass plant, the root system and leaves die, but the crown is viable and survives. What happens to that plant? Why? \_\_\_\_\_  
\_\_\_\_\_

**Match the type of grass in Column A to its characteristics in Column B.  
(Write the correct letter in the space next to the Column A number.)**

<u>COLUMN A</u> <u>Type of Grass</u>	<u>COLUMN B</u> <u>Characteristics</u>
____ 4. St. Augustine grass	a. Warm-seasoned; drought tolerant; very aggressive and fast-growing, especially in full sunlight.
____ 5. Bermudagrass	b. Shade tolerant, coarse-textured, warm-season perennial, propagated with sod or plugs.
____ 6. Bahiagrass	c. Warm-seasoned perennial; susceptible to chinchbugs, nematodes, and various diseases.
____ 7. Zoysiagrass	d. Coarse-textured, warm-season perennial; spreads with short, thick rhizomes; drought tolerant.

Match the type of cultivation in Column A to its characteristics in Column B.  
(Write the correct letter in the space next to the Column A number.)

<u>COLUMN A</u> <u>Type of Cultivation</u>	<u>COLUMN B</u> <u>Characteristics</u>
___ 8. Core aeration	a. Use of vertical knives to slice through turf and into the soil. Be sure the soil is fairly dry. The objective is thatch control.
___ 9. Forking	b. Removes soil core, opening soil to increased penetration of air and water. The purpose is to improve root depth and root intensity.
___ 10. Grooving	c. Application of a thin layer of soil (usually sandy). This layer stimulates microbial growth; microbes feed on thatch, controlling thatch buildup.
___ 11. Topdressing	d. Use of tines mounted on a weighted drum or wheel to punch holes in the sod.

END OF LESSON EXERCISES



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## APPENDIX A: SOLUTIONS TO LESSON EXERCISES

### SOLUTIONS TO EXERCISES, LESSON 1

1. A term describing the transmission states of an ecological system as it moves toward a steady state or "climax" system. (para 1-2b)
2. You are correct if you listed any four of the following:
  - ◆ Cause reduction in crop yield.
  - ◆ Increase agricultural/landscape operations cost.
  - ◆ Host undesirables such as plant diseases or insects.
  - ◆ Possibly poisonous.
  - ◆ Possible cause of allergic reactions.
  - ◆ Cause urban damage.
  - ◆ Cause aesthetic damage.(paras 1-4 through 1-10)
3. You are correct if you listed any five of the following:
  - ◆ Ornamental plants turned wild.
  - ◆ Contamination of agricultural seeds.
  - ◆ Harvested with crop.
  - ◆ Picked up by equipment.
  - ◆ Present in landscape materials.
  - ◆ Out-of-control plants become weeds.(para 1-12a through f)
4.
  - a. Wind.
  - b. Water.
  - c. Animals.
  - d. Birds.(para 1-13a through d)
5. Plant tops, root system, and seeds. (para 1-16)
6. Cultivation kills weeds by uprooting the plant so the root system dries. (para 1-18)

7. Flaming. (para 1-21)
  8. Biological. (para 1-26b)
  9. Landscape fabrics.  
Organic material.  
(para 1-19)
  10. They kill plants by melting the waxy coating on plant leaf surfaces. Plants can't retain moisture without the waxy leaf coating. (para 1-22)
- 

### SOLUTIONS TO EXERCISES, LESSON 2

1. To produce a pest-free soil. (para 2-1)
2. On release, the fumigant becomes a fume or vapor. (para 2-2)
3. You are correct if you listed any four of the following:
  - ◆ Kill weed seeds and vegetative plant parts and other soil organisms to a depth of six to eight inches rapidly.
  - ◆ Safe to use.
  - ◆ Easy to apply.
  - ◆ Inexpensive.
  - ◆ Leave soil immediately after treatment is complete so replanting can begin.(para 2-5)
4. It depletes the ozone layer. (para 2-6b)
5. 20 to 30. (para 2-7c)

6.
  - a. Liquid drench.
  - b. Injected into the soil.
  - c. Injected into irrigation systems. (para 2-8c)
7. Nematodes.  
Bacteria.  
Fungi.  
Insects.  
Weeds. (para 2-9c)
8. To use steam as a fumigant in very large areas, large equipment is needed to produce and retain sufficient steam to be effective. (para 2-10a)
9. You are correct if you listed any two of the following:
  - ◆ Intense sunlight.
  - ◆ Temperatures above 85°F.
  - ◆ Minimum of four weeks time. (para 2-11)

### **SOLUTIONS TO EXERCISES, LESSON 3**

1. Dicotyledon. (para 3-6e)
2. Monocotyledon. (para 3-6e)
3. Annual. (para 3-8)
4. Biennial. (para 3-9)
5.
  - a. The Calvin-Benson cycle (C3).
  - b. The Hatch/Slack cycle (C4) (also called the dicarboxylic acid cycle)
  - c. The Crassulacean acid metabolism cycle (CAM). (para 3-13a)
6. C4 plants are more efficient under these conditions. (para 3-13a)
7. Translocation. (para 3-16)
8.
  - a. Soil nutrients must be dissolved in water to be taken up by roots.
  - b. Water carries dissolved nutrients to leaves and sugars to roots.
  - c. Water is necessary element for photosynthesis. (para 3-21)
9. Light is the energy source driving photosynthesis. (para 3-24)
10.
  - a. Y, X.
  - b. X, Y. (para 3-24)

### **SOLUTIONS TO EXERCISES, LESSON 4**

1. b (para 4-4)
2. f (para 4-5)
3. l (para 4-6)
4. g (para 4-7)
5. a (para 4-10)
6. j (para 4-11)
7. d (para 4-9)
8. h (para 4-8)
9. e (para 4-12)
10. c (para 4-13)
11. Photosynthetic inhibitors. (para 4-15)
12. The wind may blow pesticide away from the intended area. (para 4-25)
13. Warm, calm days when no rain is expected. (para 4-31)
14. Broadleaf weeds. (para 4-38)

## **SOLUTIONS TO EXERCISES, LESSON 5**

1. Large grasshopper populations are migratory. (para 5-7)
2. The key is placing the insecticide on turfgrass leaves so the feeding larvae will ingest a lethal dose. (para 5-8)
3. To cause the spray to adhere to grass leaves. (para 5-8)
4.
  - a. Dethatch the turf.
  - b. Aerate the turf.
  - c. Water the turf.(para 5-9c)
5. Early summer is the correct time of year, early summer being the period before the adults have laid eggs. (para 5-10c)
6.
  - a. Use a low toxicity bait.
  - b. Before dying, sterile workers feed the bait to the reproductive queen--who then dies.(para 5-12c)
7. You are correct if you listed any five of the following:
  - ◆ Avoid drift.
  - ◆ Use precautions on slopes to prevent runoff.
  - ◆ Beware of possibility for groundwater contamination.
  - ◆ Avoid persistent insecticides.
  - ◆ Beware of nontarget organisms.
  - ◆ Consider heavy rain (don't treat if heavy rain is imminent)
  - ◆ Keep domestic animals and people off the treatment area.(para 5-22)
8. Sod.  
Lawn.  
Mole. (paras 5-18 and 5-19)
9. High nitrogen levels seem to make turfgrass more susceptible to chinch bugs. (para 5-13)

10. Place a properly labeled insecticide in the foliage so the spittlebugs will ingest a lethal dose. (para 5-15c)
- 

## **SOLUTIONS TO EXERCISES, LESSON 6**

1. Eastern tent caterpillar. (para 6-5 and 6-5d)
  2. Bagworm. (para 6-7a and c)
  3. Aphids. (para 6-12a and c)
  4. Bark. (para 6-19 and 6-19a)
  5. You are correct if you listed any three of the following:
    - ◆ Selection of resistant trees/shrubs.
    - ◆ Appropriate pruning.
    - ◆ Proper fertilization (avoiding excessive nitrogen).
    - ◆ Adequate watering.
    - ◆ Correct planting techniques.
    - ◆ Removal/salvage of overmature or damage plants.para 6-23)
  6. Scales. (para 6-14)
  7. Flathead. (para 6-20a)
  8. Wood borers. (para 6-22b)
  9. Gypsy moth. (para 6-9b)
  10. Forest tent. (para 6-6c)
- 

## **SOLUTIONS TO EXERCISES, LESSON 7**

1.
  - a. Completely occupy bodies of fresh water.
  - b. Destroy the natural ecosystems.
  - c. Reduce human use of water. (para 7-1)

2.
  - a. Submersed plants.
  - b. Emersed plants.
  - c. Floating plants.
  - d. Floating leaf plants.
 (paras 7-24 through 7-28)
3. You are correct if you listed any two of the following:
  - ◆ Control is immediate.
  - ◆ Immediate use of water.
  - ◆ No algae blooms are likely to form.
 (para 7-31a)
4.
  - a. Type of plant.
  - b. Herbicide restrictions.
  - c. Physical constraints.
  - d. Possible impact.
  - e. Effects on native aquatic plants.
 (para 7-45)
5. Photodegradation.  
20 days. (para 7-43)
6. Microbial.  
Charged particles.  
60-90 days. (para 7-43)
7. Insoluble compounds.  
Bonds to charged particles.  
No. (para 7-43)
8. Plants.  
Sediments.  
1-7 (para 7-43)
9. Flowering plants reproduce by producing flowers and seeds.  
Ferns reproduce by producing spores.  
(paras 7-22 and 7-23)
10. 12.4 acre feet. (para 4-46)
 
$$\frac{(120,000 \times 4.5)}{43,560} = 12.4$$
11. **NOTE: The solution for this test item has been left at the end of Lesson 7 for your convenience in understanding the steps involved in solving the problem.**

## **SOLUTIONS TO EXERCISES, LESSON 8**

1. You are correct if you listed any four of the following:
  - ◆ Nitrogen.
  - ◆ Phosphorus.
  - ◆ Potassium.
  - ◆ Calcium.
  - ◆ Magnesium.
  - ◆ Sulfur. (para 8-1b, box)
2. You are correct if you listed any six of the following:
 

◆ Boron.	◆ Chlorine.
◆ Iron.	◆ Cobalt.
◆ Manganese.	◆ Vanadium.
◆ Copper.	◆ Sodium.
◆ Zinc.	◆ Silicon.
◆ Molybdenum.	

 (Section II, box)
3. Turn brown and die. (para 8-2c)
4. Red. (para 8-5b)
5. Turn yellow uniformly. (para 8-7b)
6. Green. (para 8-8b)
7. Blacken and shrivel. (para 8-11b)
8. Adding supplemental elements to the soil to encourage plant growth.  
(para 8-17c)
9. Acid-forming fertilizer. (para 8-19)
10. Complete fertilizer. (para 8-19)
11. Obtain a value which may be used to predict the amount of fertilizer to apply.  
(para 8-20c)
12. The soil sample is representative of the land area being tested. (para 8-21)

## **SOLUTIONS TO EXERCISES, LESSON 9**

1.
  - a. Susceptible host plant.
  - b. Favorable environment.
  - c. Pathogen or causal organism.  
(para 9-3a through c)
2.
  - a. Bacteria.
  - b. Fungi.
  - c. Viruses and viroids.
  - d. Nematodes.
  - e. Parasitic plants.  
(Section III, box)
3. You are correct if you listed any five of the following:
  - ◆ Air pollutants.
  - ◆ Salt.
  - ◆ Drought.
  - ◆ Excess water.
  - ◆ Freezing.
  - ◆ Lightning.(paras 9-11 and 9-12)
4. Bacterial. (para 9-4b)
5.
  - a. Tissue necrosis.
  - b. Stunting of plant organs or entire plants.
  - c. Excessive growth of plant parts.  
(para 9-5b)
6.
  - a. Bacteria.
  - b. Fungus. (para 9-3b and 9-5c)
7. Nematodes feed on plants or inject toxic materials into plant tissues, eventually causing plant demise. (para 9-7b)
8. You are correct if you listed any three of the following:
  - ◆ Insect feeding activity.
  - ◆ Nematode feeding activity.
  - ◆ Vegetative propagation.
  - ◆ Parasitic plants.
  - ◆ Contaminated seed or pollen.(para 9-6c)
9. Taking all of the nourishment (water, minerals, and organic compounds) from the host plant. (para 9-8a)

10.
    - a. Invasion by wood boring insects.
    - b. Attack by pathogenic fungi.  
(para 9-12b)
- 
- 

## **SOLUTIONS TO EXERCISES, LESSON 10**

1. The goal of forest pest management is to maintain stands of rapidly growing trees with sufficient resources to endure feeding by insects, fungi, and other organisms. (para 10-2c)
2. Pests kill some trees. The remaining trees obtain more soil nutrients, more water, and more sunlight. These trees grow rapidly.  
(para 10-2a)
3. You are correct if you listed any four of the following:
  - ◆ Tree nurseries.
  - ◆ Seed orchards and seed.
  - ◆ Production areas.
  - ◆ Christmas tree plantations.
  - ◆ Turpentine plantations.
  - ◆ Arboreturns, research plots, or wind breaks.
  - ◆ Urban or suburban forests.(para 10-5)
4.
  - a. The method is slow.
  - b. The method takes a large investment in research and certification.  
(para 10-7d)
5.
  - a. Risk to human health.
  - b. Possible environmental damage.  
(para 10-7f)
6. Aphids, scales, and adelgids suck juices (plant nutrients) from trees and inject toxic salivary materials. The result is sick trees. (para 10-8b)

7. You are correct if you listed any three of the following:

- ◆ Planting trees in mixed stands.
- ◆ Creating mixed-age stands.
- ◆ Thinning tree stands.
- ◆ Planting improved tree varieties/species.
- ◆ Removing high-risk trees.
- ◆ Prompt salvaging of infested trees.
- ◆ Disposing of logging residues.

(para 10-9)

8. Feeding on tree seeds. (para 10-17c)

9. You are correct if you listed any five of the following:

- ◆ Fences.
- ◆ Sound and light devices.
- ◆ Barriers to protect individual trees.
- ◆ Recreational hunting.
- ◆ Seedling protectors.
- ◆ Habitat manipulation (removing food sources).
- ◆ Chemical treatments.
- ◆ Trapping and hunting of large beaver populations.

(para 10-18)

#### **SOLUTIONS TO EXERCISES, LESSON 11**

1. b. (para 11-18b)
2. a. (para 11-21a)
3. d. (para 11-4b)
4. c. (para 11-22a)
5. c. (para 11-7b)
6. d. (para 11-10b)
7. b. (para 11-14b)
8. a. (para 11-15b)
9. c. (para 11-8d)
10. d. (para 11-11d)

11. b. (para 11-13d)

12. a. (para 11-18c)

#### **SOLUTIONS TO EXERCISES, LESSON 12**

1. Plants and animals. (para 12-2)
2. Outdoor recreation. (para 12-4)
3. To defray the cost of fish and wildlife management at the installation collecting the fees. (para 12-7a(5))
4. d (para 12-9a through c)
5. a. Fish and game species present.  
b. Non-game birds common to the area.  
c. Endangered species present.  
d. Fish and wildlife potential. (para 12-7b)
6. a (para 12-8a(4))

#### **SOLUTIONS TO EXERCISES, LESSON 13**

1. Turf may be defined as a covering of vegetation plus the matted upper soil level filled with roots and/or rhizomes. (para 13-3a)
2. All growth originates from tissue in the turfgrass crown. (para 13-3b)
3. The turfgrass plant survives because the crown survives and is viable. (para 13-3b)
4. c (para 13-5h)
5. a (para 13-5f)
6. d (para 13-5i)
7. b (para 13-5g)
8. b (para 13-11a)
9. d (para 13-11e)
10. a (para 13-11b)
11. c (para 13-11g)

## STUDENT COMMENT SHEET

Subcourse number,  
title, course date.

MD0142, Department of Defense Pest Management Course, PHASE I -- 1997

Today's date

Errors in  
subcourse

Suggested changes  
in subcourse

Student rank & name

»»

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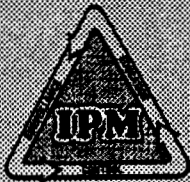
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**USES:** To make necessary changes to student records.

**DISCLOSURE VOLUNTARY:** Failure to submit SSN may prevent response to inquiries which require follow-ups.